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EXAMPLES OF MAGNETIC FIELD DETECTION USING CHAOTIC ELECTRONIC CIRCUIT

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1. INTRODUCTION

Magnetic sensing techniques exploit a broad range of ideas and phenomena from the fields of physics and material science (Lenz & Edelstein, 2006). The most common sensors are: search-coil sensors based on Faraday's law of induction (conductive materials approaching the active coil induce eddy currents and produce its inductance change), the Hall effect sensors (a voltage difference appears across thin rectangle of conductor or semiconductor when an electric current is sent along its length), magnetoresistive sensors (use a change in resistance caused by external magnetic field called anisotropic magnetoresistance AMR occuring in permalloy or giant magnetoresistance change GMR achieved in layered structures ferromagnet/conductor), magnetostrictive sensors (magnetostrictive material dimensions depend on the direction and magnitude of an external magnetic field) and fluxgate sensors (consist of a ferromagnetic material wound with two coils, a drive coil with sinusoidal current driven the core into saturation and a sense coil which signal depends on an external magnetic field). One of the methods of developing the magnetic field detection technology is the use of new physical phenomena.

In the 70s of the 20th century irregular seemingly random dynamical behavior of deterministic systems very sensitive on initial conditions attracted attention and the term chaotic dynamics was introduced to characterize this behavior (Gleick, 1987). Since then, chaotic dynamics has become the subject of intense investigations in different areas of science (Strogatz, 2018). Moreover, chaos is predicted to play diverse functional roles in living systems (Teodorescu, 2000). Systems the most often used in experimental studies of chaotic dynamics are electronic circuits. They are easy to design, build and measure, they operate in real time and their component values are easy to adjust. The first electronic circuit in which chaotic dynamical behavior was experimentally observed was Chua's electronic circuit invented in 1983 (Chua, 1992). It is the only real physical system in which chaos has been observed numerically, experimentally and it has been proved mathematically (Zhong and Ayrom, 1985). The dynamical trajectory of chaotic system in the phase space tends to evolve to a subset of the phase space for a wide variety of starting conditions of the system called the attractor (Milnor, 1985). The attractor can take the form of fixed point, periodic orbit or chaotic i.e. strange attractor. In chaotic systems a small smooth change made to system parameter causes a sudden change in its attractor, what is called bifurcation.

In recent years sensors based on chaotic systems and measuring technique using properties of chaotic dynamics have been proposed. These sensors relate variations of a signal the sensor measure with variations of a parameter characterizing deformations of an attractor, or operate in the vicinity of the bifurcation point where very small change of the sensed signal causes sudden significant change of the attractor shape. There are also bistable sensors with measurement technique similar to fluxgate sensors technique which use fast jumps of dynamic trajectory between two different regions of the phase space caused by the measured signal. Some examples of such sensors have been presented at 1st International Symposium in Electronic Engineering, Information Technology & Education, EEITE2019 (Korneta, 2019).

In the last decade the effect of magnetic field on systems with chaotic dynamical behavior has started to attract attention (Korneta et al., 2021, Silva et al., 2021, Karimov et al., 2019 and 2022). The aim of this presentation is to provide examples of how weak and moderate magnetic fields are detected using Chua's electronic circuit.

2. MATERIALS AND METHODS

Chua's electronic circuit is made up of one resistor, one inductor, two capacitors and one nonlinear element called Chua's diode characterized by a three-segment piecewise-linear current-voltage curve which can be made using multiple electronic discrete components (Kennedy, 1992, O'Donoghue, 2005)), or as an integrated circuit device (Cruz et al., 1992). Diagram of the electronic Chua's circuit with its inductor placed inside an air core large coil L_e that produces the magnetic field and the voltage source E(t) is shown in the figure 1.

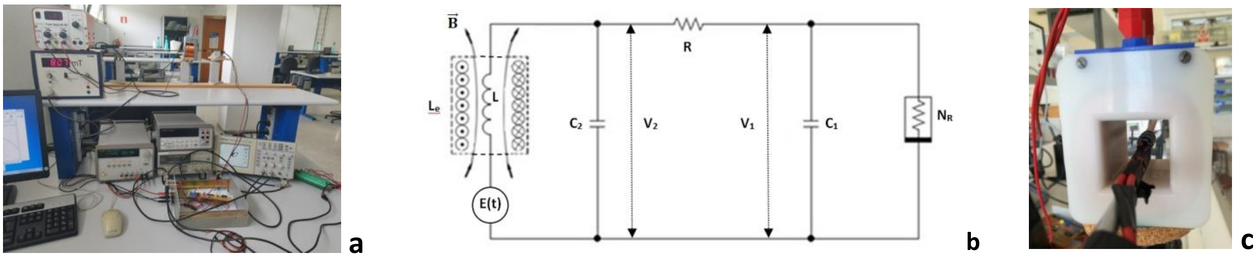

Figure 1. The experimental setup (a) to study the effect of magnetic field on Chua's electronic circuit (b). C_1 = 10 nF, C_2 = 100 nF, L = 18 mH, N_R is the Chua's diode, R is the variable resistor and E(t) is the voltage source. The large coil L_e produces external magnetic field with the magnetic induction B acting on the Chua's circuit inductor L (c).

By changing the value of the resistance R, the capacitance C_1 or the inductance L, Chua's circuit exhibits a sequence of bifurcations and it can be in equilibrium, periodic, period-doubling and chaotic single scroll or double scroll regimes (Ayrom, 1986). The phase portraits of two single scroll chaotic attractors selected depending on the uncontrollable initial conditions and the double scroll chaotic attractor are shown in figure 2.

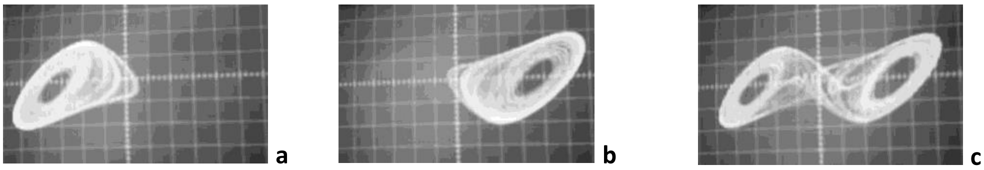

Figure 2. Experimental phase portraits of two single scroll chaotic attractors (a and b) and the double scroll chaotic attractor (c) taken from oscilloscope. Horizontal axis: V_2 500 mV/div, vertical axis: V_1 1 V/div.

In the single scroll chaotic regime the dynamic trajectory is characterized by irregular oscillations with frequencies around a certain dominant value. The chaotic double scroll attractor consists of two scrolls located in different regions of the phase space connected by swirling lines corresponding to fast jumps between them. The example of temporal evolutions of the voltage V_1 on the capacitor C_1 and the voltage V_2 on the capacitor C_2 in this case are shown in figure 3. The time series V_1(t) can be characterized by the step function $\Theta(t)$ identifying the part of the attractor in which dynamic trajectory is located and its derivative the spike function $S(t)$ identifying crossing points between them. These crossing points correspond to spikes of firing neuron (Kreiman, 2004).

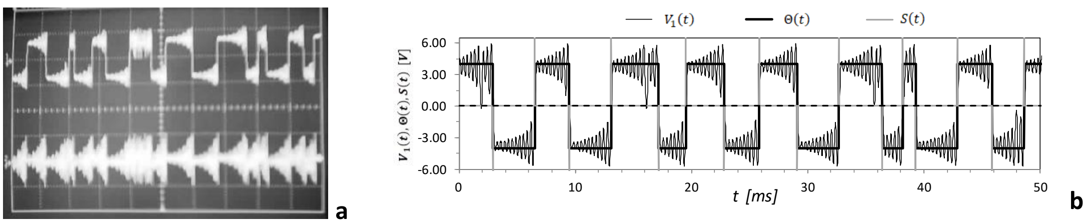

Figure 3. Temporal evolutions of voltages V_1 and V_2 in the double scroll chaotic region taken from oscilloscope (a) and recorded with sampling rate of 50 kHz with the step function $\Theta(t)$ and the spike function $S(t)$ (b).

The methods to detect and measure the magnetic field acting on Chua's circuit inductor are based on changes of the Chua's circuit operation regime between the single scroll and double scroll chaotic regimes and the use of observables determined from the step and spike functions.

3. RESULTS AND DISCUSSION

Recently it has been shown that Chua's electronic circuit operating in chaotic regime can be used to detect and measure external sinusoidal weak magnetic field signal with the amplitude below 1 mT and frequencies in kHz range (Silva et al., 2021) and static moderate magnetic fields in the range 5-20 mT (Korneta et al., 2021).

3.1 The method to detect weak periodic magnetic field signals

Nowadays, the noise in electronic circuits is considered as unavoidable, unwanted, irregular signal, or as a useful signal that can facilitate the detection and transmission of weak signals by the stochastic resonance effect (Gammaitoni et al., 1998). The stochastic resonance occurs when the response of nonlinear dynamical system to weak input signal is enhanced by the presence of the noise tuned to the optimal level. It requires a form of threshold, subthreshold input signal and a source of noise with small correlation time. Most of the research on stochastic resonance has focused on bistable systems with two stable equilibria, sinusoidal signal and the Gaussian white noise. Neither the external periodic forcing nor the noise were able to switch the system from one state to another. Only a combination of these two factors could cause jumps between the two states. The stochastic resonance effect can also be observed in chaotic systems whose dynamical trajectories have different preferred regions in phase space called chaotic attractors. These chaotic systems can be considered as a form of a bistable system. Korneta et. al. (2006) presented the stochastic resonance effect in an electronic Chua's circuit whose dynamics switches between two different stable single scroll chaotic attractors when it is driven by a periodic voltage signal and a Gaussian white noise voltage.

The experimental setup shown in figure 1 was used to detect periodic magnetic field external signals with intensity below 0.25 mT, induced by large coil L_e , with frequencies between 1 kHz and 4 kHz by using the internal voltage Gaussian noise generated by the noise source placed in series with the Chua's circuit inductor L . Initially, Chua's electronic circuit was operating in the single scroll chaotic regime near the double scroll regime. For each frequency the intensity of the external periodic magnetic field was set just below the appearance of trajectory jumps between two chaotic scrolls. In the frequency range 1-4 kHz these intensities were the smallest. Switching on the internal noise with sufficient intensity, crossings between the two single scroll attractors were induced. For low noise intensity crossings are very rare and their rate increases with increasing the noise intensity. The stochastic resonance effect was shown and quantified by a peak in the power spectrum of the step function $\Theta(t)$ shown in figure 2. The signal to noise ratio SNR defined as the height of the signal peak divided by the noise background level, measured in the considered power spectrum had a maximum for the noise intensity around 0.15 V rms. The stochastic resonance effect has also been confirmed by the structure of the residence time distribution, which consists of peaks modulated by an envelope located at multiples of the half of the forcing signal period. The residence time is defined as the time intervals that the trajectory spends in each scroll of a chaotic attractor.

3.2 The method to detect moderate static magnetic field

One of the operation methods of sensors based on chaotic systems uses changes of the sensor operation regime produced by the change in the measured signal (Teodorescu et al., 2002). If the operating point of the sensor is near a sharp transition in the bifurcation diagram, any small change in a target signal generates a dramatic change in the system's dynamic trajectory, which can easily be detected. Korneta et al. (2021) proposed biomimetic sensor based on electronic Chua's circuit operating in chaotic double scroll regime to detect and measure static and low frequency moderate magnetic fields. In the double scroll regime there are fast jumps between two scrolls of the double scroll attractor. Increasing the external magnetic field intensity acting on Chua's circuit inductor L increases the residence time of dynamic trajectory in one scroll up to the threshold, where the chaotic attractor changes from double scroll to single scroll and jumps disappear. This effect was quantified by the spike count rate with spikes defined by crossing points between scrolls. At the threshold the spike count rate falls from several hundred per second to zero what can easily be noticed and detected. The threshold magnetic field intensity increases with decreasing the resistivity of Chua's circuit. The external magnetic field intensity is measured by determining the value of Chua's circuit resistance at the threshold. By combining several independent Chua's electronic circuits, one can get a sensor with every desired transfer function determined by the combination of individual Chua's circuits spike count rates.

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Bias Stress Effect in Poly(3-hexylthiophene) Thin Film Transistors Operating in Irradiation-activated Electrolyte

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1. ABSTRACT

In the present work, we report on electrolyte-gated organic thin-film transistors (EGOTFTs). This class of devices has potential for a broad range of applications spanning from printable complementary logic circuits to (bio)chemical/physical sensors, but to progress further requires a better understanding of how, and to what extent, materials properties correlate with device operation. The present study provides insight into EGOTFTs stemming from in-situ photo-induced-generation of mobile ions in polymeric gate dielectrics. The system chosen involves a p-type semiconducting material (poly(3-hexylthiophene) - P3HT) and gate dielectrics based on poly(methyl methacrylate) (PMMA) containing a photoacid generator (PAG) for producing upon UV irradiation an electrolyte with potentially mobile ions. We investigate the influence of the gate bias stress on transistors having high conductivity poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS) gate electrode. Modulation of the source-drain output current (I_{DS}) occurring with the application of gate-voltage (V_{GS}) in the continuous mode is examined as a function of different processing parameters. Particular emphasis is placed on stress experiments as a function of the applied V_{GS}, the source/drain electrode material, channel length and P3HT thickness. They show that I_{DS} monotonically increases with time, evolving from a superlinear power-law regime to a sublinear regime, where the contact resistance gradually dominates the total resistance of the devices as the stress time increases. At long stress times, I_{DS} depends very little on the channel length and is dominated by S/D contact resistances. I_{DS} as time tends to infinity decreases as the thickness of the P3HT increases, thus indicating an enhancement of the contact resistance with the P3HT thickness. These results suggest that the devices under examination operate in the field-effect regime and do not exhibit bulk electrochemical doping. We cannot exclude the possibility that some degree of ion migration into the semiconductor layer due to the electrical bias stress also lead to a partial oxidation of P3HT most superficial layer. This interfacial region seems to be the same region involved in the field-effect accumulation of charge carriers.

2. INTRODUCTION

Electrolyte-gated organic thin film transistors (EGOTFTs) have potential for a fascinating range of applications like switching devices for flexible displays, complementary logic circuits, memory devices, light-emitting transistors, and (bio)chemical/physical sensors [1]. However, their widespread exploitation is still limited by their poor understanding of how, and to what extent, materials properties correlate with device operation. To progress beyond the stage of demonstration, it is important to identify and quantify as much as possible the parameters associated to these processes and develop simple tractable models that can relate materials properties with device performance. In this work we investigate the influence of the gate bias stress on solution-processed EGOTFTs operating in irradiation-activated electrolyte consisting of photoacid generator salt (PAG: triarylsulfonium hexafluoroantimonate (TPS-SbF_6)), dispersed in poly(methylmethacrylate) (PMMA) [2]. Top-gate (high conductivity poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS)) bottom-contact (Au/ or ITO (60 or/ 100 nm-thick) source (S) and /drain (D) electrodes) p-type (regioregular poly (3-hexylthiophene-2,5-diyl) (P3HT))-based transistors are studied in the linear operation regime under the application of a gate bias (V_{GS}) in the continuous mode. *IDS* is recorded at the drain electrode by applying a square pulsed S/D voltage (-1V/0.2 s) at limited time intervals. Modulation of the source-drain output current (I_{DS}) under application of different continuous gate bias stress is examined as a function of the following three processing parameters: (1) the S/D electrode material, (2) the channel length and (3) the thickness of the P3HT layer. No dependence of maximum I_{DS} as time tends to infinity occurs for Au S/D electrode devices at applied gate voltages in the -5V to -35V range. The same trend in the maximum recorded IDS versus applied gate voltages occurs for interdigitated ITO electrodes. Similar maximum I_{DS} are recorded for Au electrodes devices with a channel length (CL) in the 0.1 - 10 μm range. As compared to the Au S/D electrode devices, UV-irradiated devices with interdigitated ITO electrodes (with variable 50-150 μm CL and channel width, W=30 mm), using a 350nm-thick PAG-PMMA layer formed onto a 20 or 50 nm-thick P3HT layer exhibit the same trend in the maximum recorded I_{DS} (V_{GS}=-25V). This clearly reveals that at long stress times, I_{DS} depends very little on the channel length and is dominated by S/D contact resistances. I_{DS} as time tends to infinity decreases as the thickness of the P3HT increases, thus indicating an enhancement of the contact resistance with the P3HT thickness.

3. MATERIALS AND METHODS

Materials: Regioregular poly (3-hexylthiophene-2,5-diyl) (P3HT) with regioregularity = 97.6% and Mn = 60000-110000 (Ossila Ltd) were used as bought without further purification or treatment. Poly(methyl methacrylate) (PMMA) with 996000 molecular weight was purchased from Sigma-Aldrich. Triphenylsulfonium hexafluoro antimonate (TPS-SbF_6) salts were obtained from Midori Kagaku Co. The following solvents have been used for dielectric and semiconductor formulations: methyl isobutyl ketone (MIBK, Sigma-Aldrich), chloroform ($CHCl_3$, Merck). Hexamethyldisilazane (HMDS) and Hellmanex® III were purchased from Microchemicals and Ossila, respectively. PEDOT-PSS (PH1000) was obtained from Ossila.

Film thickness and UV-exposure: Film thickness was determined by profilometry using an Ambios Technology XP-2 profilometer. Ultra-violet (UV) irradiation was performed in air using an Oriel Hg−Xe 600 W exposure tool through a 254 nm narrow band filter (10 nm bandwidth at half-maximum). The incident power of the resulting deep-UV radiation through the 254 nm filter was measured to be 24 $\mu W \cdot cm^{-2}$. The samples were irradiated for 250 s resulting in a dose of 6 mJ cm^{-2}.

Device Fabrication: The source-drain (S-D) electrodes were made of Au or ITO materials corresponding to two different physical layouts (see Fig. 1(a) and (b)). Au electrodes were formed on a 100 nm-thick SiO_2 film thermally grown on a 4-inch Si wafer. Electrode patterning was carried out by e-beam lithography and lift-off of a sputtered Cr/Au (3/60 nm-thick) bilayer. Afterwards the wafer was cut into 2 x 2 cm^2 pieces, each of them containing multiple isolated Au electrodes of 500 μm width (*W*) with a gap (i.e., a S/D separation length, *L*) ranging from 0.1 to 10 μm. ITO (100nm-thick) S/D electrodes patterned on 1.5 x 2 cm^2 glass samples with a 20nm-thick SiO_2 coating on top were obtained from Ossila Ltd. They consist of interdigitated fingers (see Fig. 1(b) with variable 50-150 μm channel length and channel width W=30 mm. Cleaning of the samples was carried out by (a) successive sonication in acetone and isopropanol, rinsing in 25 ^oC deionized (DI) water and nitrogen blow-drying for the Au electrodes and (b) sonication in hot (60 ^oC) 10% NaOH for 5 min / rinsing in 25 $_oC$ DI water / sonication in hot (60 ^oC) 2% Hellmanex for 5 min / rinsing in 50 ^oC DI water / sonication in 50 ^oC IPA for 5 min / rinsing in 50 ^oC DI water / nitrogen blow-drying. Next, HMDS was spin-coated on the

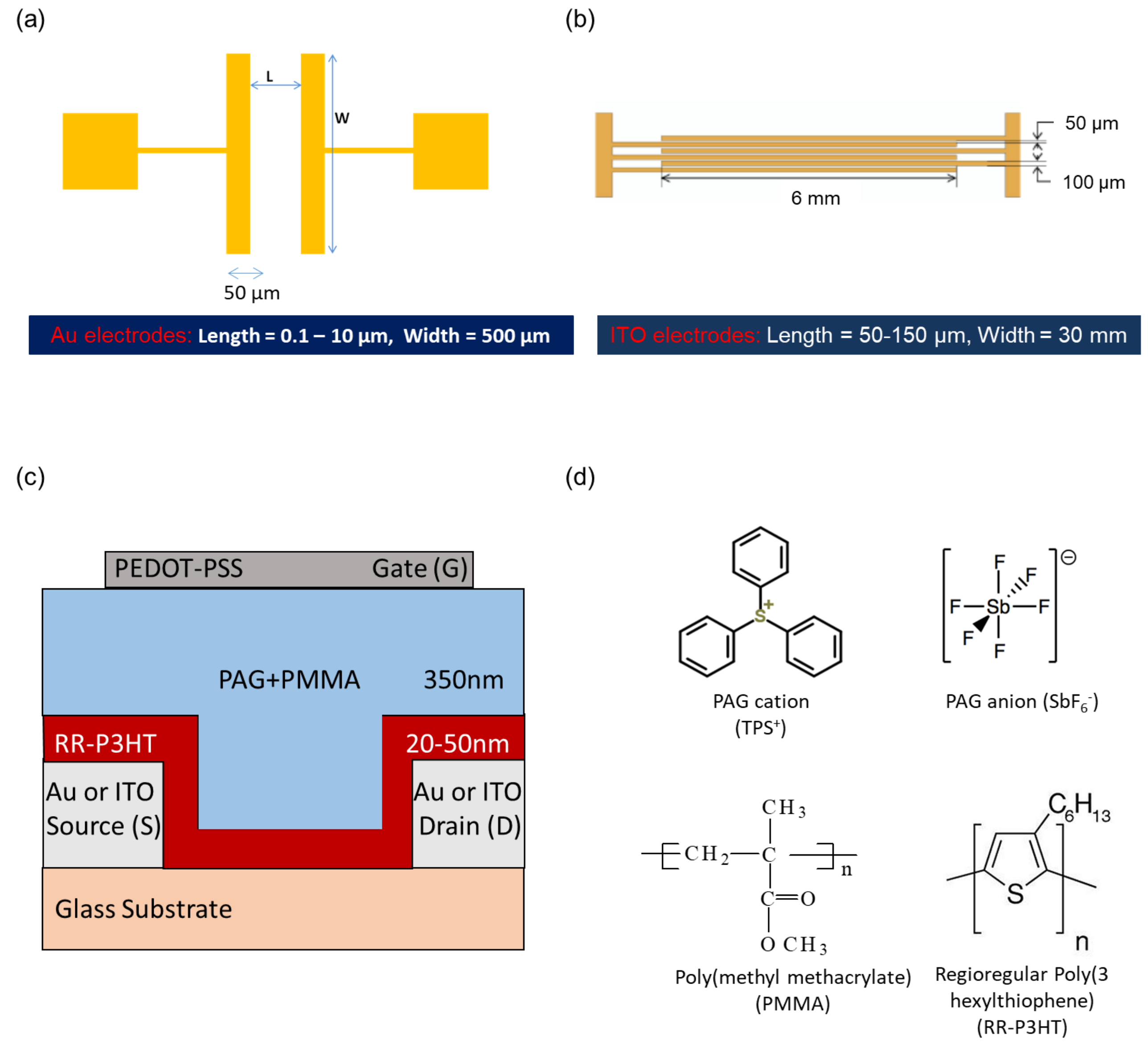

Figure 1:(a), (b) Schematicdrawingsofthe source (S) and drain (D) electrodelayoutused in top-gate bottom-contact p-type OFETs examined in this study. The twoconductivecontactsarepatterned on a glass (SiO_2) substrate. (a) Cr/Au (3/60 nm-thick) electrodes and (b) interdigitatedindium-tin-oxide (ITO, 100 nm-thick).electrodes.(c) Cross-section schematic of the top-gate bottom-contact p-type OFETs.The S and D electrodes consist of Au or ITO materials corresponding to two different physical layouts (a) and (b), respectively. The thickness of the spin-coated semiconductor material (regioregular P3HT) is in the 20-50 nm range. Subsequently, a 350nm-thick PAG-PMMA layer was formed on top of the P3HT layer. The PAG used in this work is an ionic salt consisting of [TPS] cations and [SbF_6] anions. The gate electrode consists of drop-cast PEDOT-PSS. (d) Chemical structure of PAG cation, PAG anion, PMMA and RR-P3HT. The photoacid generator (PAG) cation is responsible for the absorption of radiation and generation of protons.

substrates at 2000 rpm for 30 s prior to deposition of the P3HT materials. Before HMDS treatment, the samples were exposed to an oxygen plasma to modify the WF of the S-D electrodes. Then, P3HT dissolved in chloroform at 5 mg ml^{-1} concentration was spin-coated on the substrates. The resulting 20 nm (5 mg ml_{-1} concentration, 4000 rpm), 50 nm (5 mg ml^{-1}, 1000 rpm) thick P3HT layers were used for the devices examined in this study. A thermal treatment under ambient conditions for 5 min on a hotplate set to a temperature of 130 ^{o}C was applied after P3HT deposition. Subsequently, a photoacid generator (PAG)-containing-PMMA layer was formed on top of the P3HT layer. The PAGs are ionic salts consisting of a triphenyl sulfonium cation $[TPS]^{+}$ and a hexafluoro antimonate $[SbF_6]^{-}$ anion. PAG salts (TPS-SbF_6, 17.7 w/w in polymer) were added to already diluted PMMA solutions at equimolar concentrations. The PAG containing PMMA solutions were then spin-coated at 8000 rpm for 80 s, followed by a thermal treatment at 80 ^oC for 5 min in air. Following formation of the PAG-PMMA layer, some devices were UV-irradiated for electrolyte production as reported here above. Each sample contain five devices, four of which were irradiated and one was kept non-UV exposed (reference device). Finally, fabrication of the gate electrode was carried out by drop casting of PEDOT:PSS over the device channel under ambient conditions and drying in vacuum overnight at 25 °C.

Electrical characterization: The electrical characterizations of the devices were performed with a probe station connected to a Keysight B2912A Source/Measure unit and the electrical contacts were ensured by three micromanipulators. The $I_{DS} - t$ measurements were performed in the common source configuration and the transistors operated in the linear regime. *IDS* was obtained by applying a fixed voltage at the gate and a square pulsed voltage at the drain (- 1 V / 0.2 s) at limited time intervals (i.e., V_D was fixed at 0 V outside the data acquisition time) to limit as much as possible the overall charge flowing through the channel, which could induce channel degradation with time. The constant voltage values for the gate V_{GS} set in the -5V to -35V range. After stressing, $I_{DS} - V_{DS}$ measurement was performed for all devices by applying symmetric (from +1 V to -1 V and -1 V to +1 V) voltage sweeps. All measurements were performed at room-temperature in dark conditions.

4. RESULTS AND DISCUSSION

Figure 2(a) shows the I_{DS}-t characteristics in logarithmic representation of UV-irradiated devices with Au S/D electrodes, using a 350nm-thick PAG-PMMA layer formed onto a 20 nm-thick P3HT layer under fixed V_{GS}=-25V. Similar I_{DS} as time tends to infinity are recorded for devices with a channel length (CL) in the 0.1 - 10 µm range. As compared to the Au S/D electrode devices, UV-irradiated devices with interdigitated ITO electrodes (with 50 and 150 µm CL and channel width (CW), W=30 mm), using a 350nm-thick PAG-PMMA layer formed onto a 50 nm-thick P3HT layer exhibit the same trend in the maximum recorded I_{DS} (V_{GS}=-25V) as depicted in Figure 2(b). Figure 2(c) shows the $I_{DS}-V_{DS}$ characteristics of devices formed onto a 50 nm-thick P3HT layer with a channel length of 50, 75, 100 and 150 µm before V_{GS} application (fresh conditions) and after a stress time. I_{DS} recording during stressing was performed on the 150 µm-L device. After stressing, $I_{DS}-V_{DS}$ measurement was performed for all devices by applying symmetric (from +1 V to -1 V and -1 V to +1 V) voltage sweeps. After stress, all devices exhibit similar currents. Figure 2 clearly reveals that at long stress times, I_{DS} depends very little on the channel length of the transistors and is dominated by S/D contact resistances. The impact of V_{GS} on the output current for V_{DS}=-1 V as a function of time has been tested for UV-irradiated devices, using 20 nm-thick P3HT layer, with Au S/D electrodes (with 1 µm CL and 500 µm CW) and interdigitated ITO S/D electrodes (with 50 µm CL and 30 mm CW). The recorded I_{DS}-t characteristics for V_{GS} fixed at -35 V, -25 V, -15 V, -10 V and -5 V are shown in Figure 3. I_{DS} as time tends to infinity is virtually independent on the applied gate voltage for -5 V ≤ V_{GS} ≤ -35 V. This suggests the effect of a I_{DS} limiting factor in the form of contact resistance. Figure 4 shows stressing experiments conducted on devices with different P3HT thicknesses. $I_{DS} - t$ measurements were performed on devices with 20 nm and 50 nm-thick P3HT layers. I_{DS} as time tends to infinity decreases as the thickness of the P3HT increases, thus indicating an enhancement of the contact resistance with the P3HT thickness. From these experiments, it appears that the devices under examination operate in the field-effect regime and do not exhibit bulk electrochemical doping.

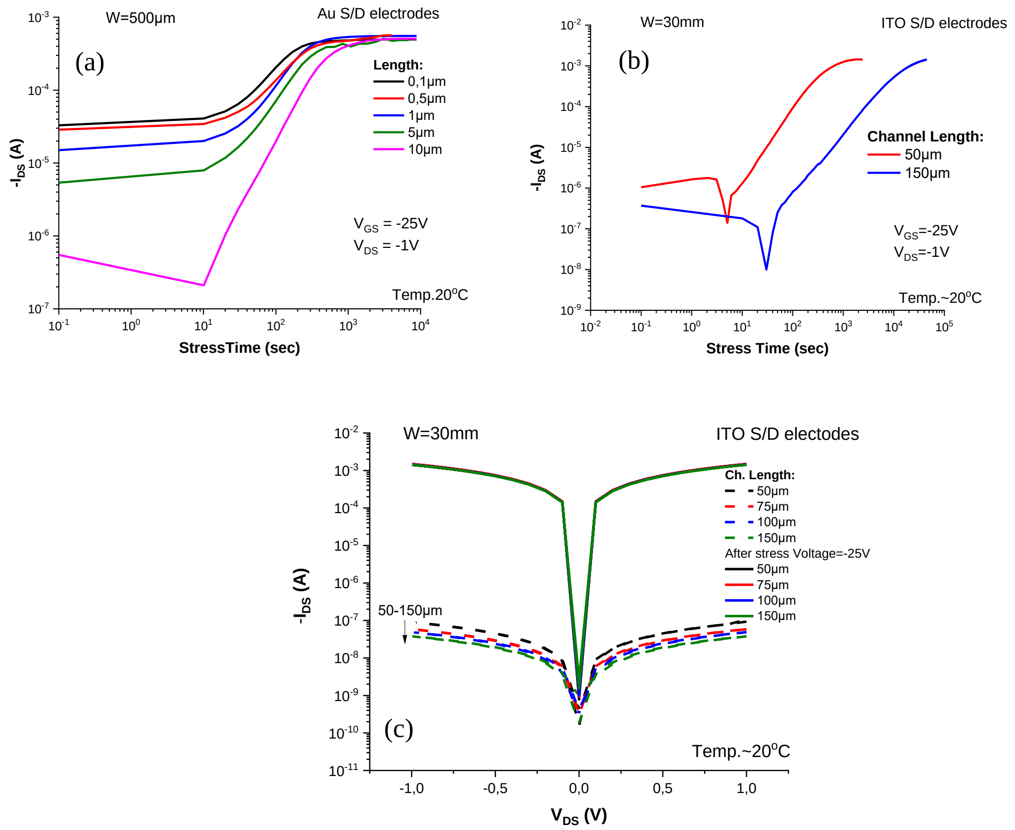

Figure 2: (a) Characteristic I_{DS}-t in log-scale EGOTFTs with Au S/D electrode for different channel lengths ranging from 0.1 to 10 μm and W=500μm, with 20nm thick P3HT layer under constant gate voltage V_{GS}=-25V. (b) Characteristic I_{DS}-t for EGOTFTs with ITO S/D electrode for two different channel lengths 50 and 150μm and W=30mm, with 50nm thick P3HT layer under constant voltage V_{GS}=-25V. (c) Characteristic I_{DS}–V_{DS} of two terminal EGOTFTs, with ITO S/D electrode for different channel lengths from 50 to 150μm and W=30mm, with 50nm thick P3HT layer before and after applying constant gate voltage (V_{GS}=-25V). The channel current after applying the constant gate voltage is the same at all channel lengths.

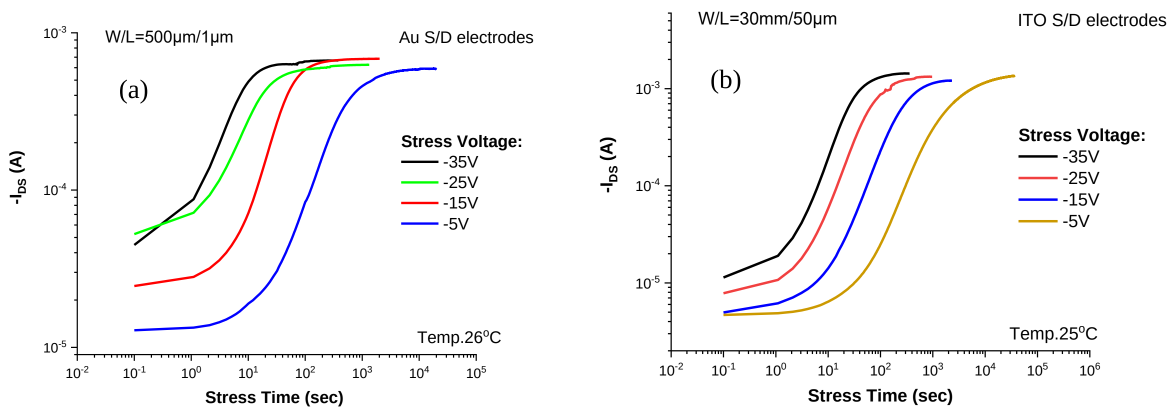

Figure 3: Characteristic I_{DS}-t in log-scale EGOTFTs with 20nm thick P3HT layer under different applied constant gate voltages (V_{GS}) in the -5V to -35V range, for (a) Au S/D electrode devices with channel length 1 μm and W=500μm and (b) interdigitated ITO electrode devices with channel length 50 μm and W=30mm.

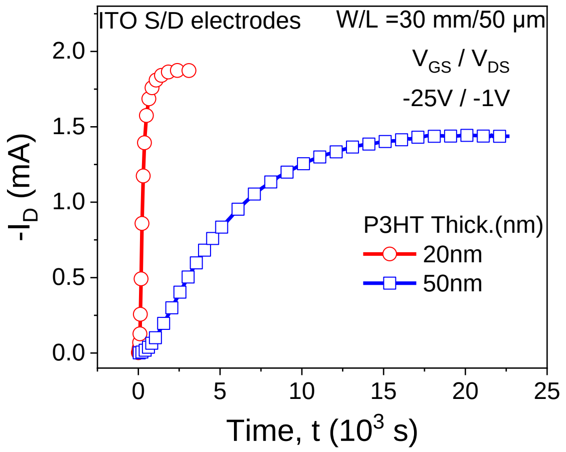

Figure 4: $I_D - t$ characteristics with interdigitated ITO electrodes, using a 20 or 50 nm-thick P3HT layer.

5. Conclusions

We provide insight into the operation of electrolyte-gated OFETs (EGOFETs) stemming from in-situ photo-induced-generation of mobile ions in polymeric gate dielectrics. We investigate the effects of the gate bias stress on p-type semiconducting material (P3HT) and gate dielectrics made of triphenylsulfonium ([TPS]+) hexafluoroantimonate ([SbF6]-) salts dispersed in PMMA. Such salts can be used as photoacid generators (PAGs) and proper exposure to UV-irradiation produces an electrolyte in the form of a strong acid (H+ [SbF6]-) with potentially mobile anions and protons in the PMMA matrix. No dependence of maximum recorded I_{DS} on V_{GS} occurs at applied gate voltages (-5 V ≤ V_{GS} ≤ -35V). Similar I_{DS} as time tends to infinity are recorded for devices with Au S/D electrodes (or interdigitated ITO electrodes) and channel length (CL) in the 0.1 - 10 μm (or 50 – 150 μm) range. At long stress times the contact resistance (R_C) dominates the total resistance of the devices R_c increases with the P3HT thickness. These results suggest that the devices operate in the field-effect regime and do not exhibit electrochemical doping in the overall volume of the P3HT. While some degree of ion migration into the P3HT under bias stressing and subsequent partial oxidation of a superficial P3HT layer cannot be excluded, this “doped” interfacial layer seems to be the same as the one corresponding to the field-effect accumulation of charge carriers (i.e., the transistor channel).

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Early Consideration on an Active Mitigation System for CubeSat Reaction Wheels Magnetic Field

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1. INTRODUCTION

The reaction wheel assembly (RWA) is currently the main technology for the attitude control in CubeSats. Normal operation of the reaction wheels unfortunately can cause various interferences on satellite's sensitive payload. Past space science missions reveal that the main source of magnetic disturbances and electromagnetic interference on mission payload's smooth operation are the attitude control systems, specifically the reaction wheels assembly, Nicolai et al. (2022), Nicolai et al. (2019). Reaction wheel components such as the electric motor and various ferromagnetic parts at high-speed operation result in significant electromagnetic stray fields in various frequency ranges. Usually, the majority of space mission have strict magnetic cleanliness requirements, Pronenko et al. (2016), Michelena et al. (2019), Nikolopoulos et al. (2020), Narvaez (2004), Mehlem and Wiegand (2010). Main approach to overcome this issue is to provide additional magnetic shielding to the attitude control subsystem that has an impact on the total weight of the microsatellite. Another mitigation strategy is placing the sensitive equipment as far as possible from the radiating sources, but this has no application in the small satellite structures (MicroSats, CubeSats, etc). Previous studies towards this direction have been done in the past, but nowadays other mitigation techniques are proposed that virtually try to minimize the magnetic fields on sensitive satellite areas, Nicolai et al. (2022), Nicolai et al. (2019). The knowledge of the magnetic behavior of the RWA can actively cancel the interference at any given area by generating an opposite magnetic field. Thus, knowing the exact voltage driven RWA behavior can easily adjust the mapping between the produced interference and the current of the "canceling" source's magnetic field. Since the scientific goals on every mission vary, cleanliness requirements are also different with range from DC magnetic fields up to a hundred of Hz (slowly varying magnetic fields of planets, plasma turbulence, etc.), Vaivads et al. (2016), Soucek et al. (2016), Capsalis et al. (2019), Braukhane et al. (2016). Thus, the study and modeling one of the main sources of magnetic disturbances is imperative. Authors in this work construct an attitude control subsystem comprised of 4-reaction wheels and present the basic principle of operation behind the magnetic behavior. Furthermore, magnetic signature measurement of a common topology, set of four reaction wheels embedded in an 1U 3D-printed enclosure, are presented. This paper provides the measurements of the magnetic signature of a set of 4 reaction wheel assemblies and a preliminary cleanliness assessment targeted to CubeSat implementation..

2. MAGNETIC FIELD GENERATION AND MEASUREMENT SETUP

Multiple magnet pairs and wire windings are used in the rotor and stator respectively to achieve smooth torque output. The magnetic field emissions of a rotating Brushless DC (BLDC) Motor can be attributed to two sources, rotating a bunch of permanent magnets (i.e. the rotor) with a certain frequency which will produce a spectral component at the frequency of the mechanical rotation, and powering the three phases of the stator in order to create the rotating magnetic field which turns the rotor. The spectrum of these currents can be obtained by examining the sensorless driving scheme. For a three phase BLDC motor with a sensorless driving scheme (driven without Hall sensors, using

the back EMF instead), at each state two phases are powered (opposite to one another) while the third is used as an input by the Speed Controller to identify the correct moment for state transition. That's the reason why BLDC motors driven sensorlessly cannot operate at very low speeds (lower than 1300 rpm approximately for our case), as an adequate speed is required for a large enough back EMF voltage to be induced to the coil of the "sensing phase".
The process described above (at each state 2 opposite powered phases) produces 6 possible combinations for the current in the stator coils. The sequence of those 6 states comprises a signal cycle (electrical cycle).

A mechanical cycle should not be confused with a signal cycle, which is influenced by the number of permanent magnetic poles on rotor. Multiple poles are used to maximize the mechanical torque for a given electrical torque, but each pole pair requires one signal cycle for one mechanical rotation.

$$f_{sc} = N_p \cdot f_{mech} \qquad [1]$$

where,

$$N_p = number\ of\ pole\ pairs$$

Typical BLDC motors used in RC cars or drones have 14-16 poles to achieve large mechanical torque while minimizing the required current. Our motors have 14 poles, therefore 7 pole pairs. The number of signal cycles per second (for the current powering the stator's phases) can be obtained by multiplying the $\boldsymbol{f_{mech}}$ with the number of pole pairs on the rotor. Therefore, these currents' digital waveforms have a fundamental frequency of $\boldsymbol{f_{sc}}$, producing emissions at $\boldsymbol{f_{sc}}$ and its harmonics, based on literature, Nicolai et al. (2022). This is also verified by the measurements where spectral components at $\boldsymbol{f_{mech}}$, $\boldsymbol{f_{sc}}$ and $5 \cdot \boldsymbol{f_{sc}}$ are observed (Fig. 2)

The first step on creating an active system capable of cancelling the emissions of the RWA at a certain point, is the accurate modeling of the motor's emissions. To model the rotor's magnetic field emissions, each of the 14 permanent magnets is represented with a magnetic dipole, where the moment direction rotates over a full circle with a constant frequency equal to $f_{mech} = \frac{360}{14}\text{deg} = 28.714\ deg$ represents the interval between sequential dipole moment directions.

In order to evaluate the real time contribution of the 4-reaction wheel system, the measurement layout depicted in Fig.1 has been implemented. Two fluxgate magnetometers have been placed perpendicular to the 1U (CubeSat like) structure which is embedded in a gimbal arrangement in order to be able for a 3-D movement.

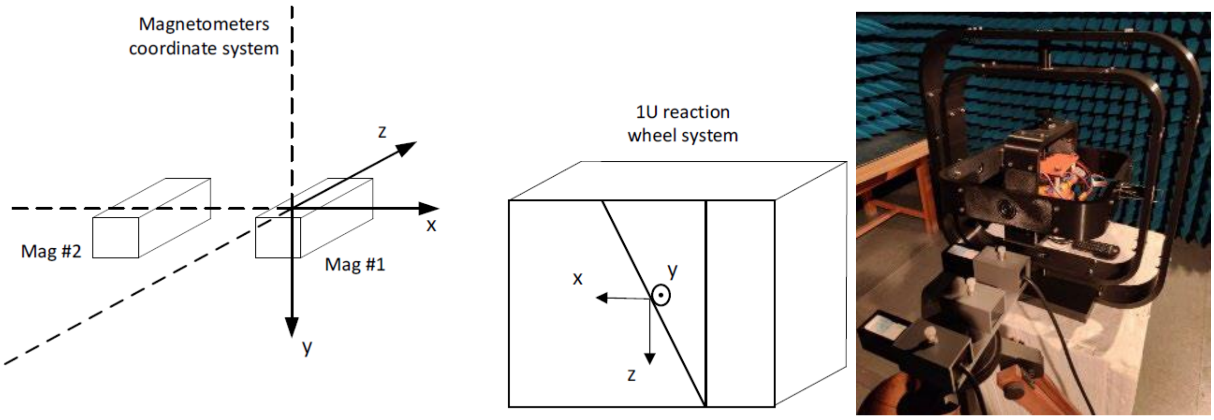

Fig. 1. Measuring layout in respect to the corresponding coordinate systems.

An intensive measurement campaign, as well as baseline wheel simulation and component analysis, Nicolai et al. (2022), yielded a thorough knowledge about the magnetic sources in the baseline wheel. Magnetic materials were identified and exchanged where possible. The main disturbing frequencies of the motor could be verified by test and simulation and are:

- The mechanical rotation frequency f_{mech}, caused by the single dipole behavior of the motor in the far field (due to the rotor back iron dipole)
- The electrical rotation frequency $f_{sc} \cdot N_P$, were N_P is the number of pole pairs
- The harmonics of these, especially the 3rd and the 5th of the electrical rotation frequency

Measurements with a 7-pole reaction wheel that was used in this work reveal these main frequencies.

3. RESULTS AND DISCUSSION

The following figure depict the results of the measured magnetic behavior of one reaction wheel (motor1) in order to calculate its magnetic moment (source of interference).

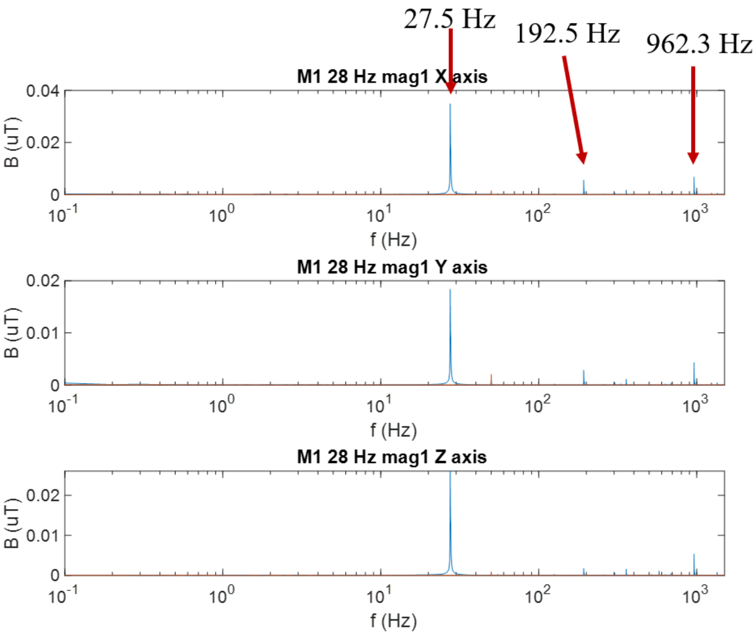

Fig. 2. Emissions at f_{mech} , f_{sc} and $5 \cdot f_{sc}$

The predicted value (algorithm solution) for the magnetic moment of the 14 dipoles is about 1.671 mA·m^2 for Motor1

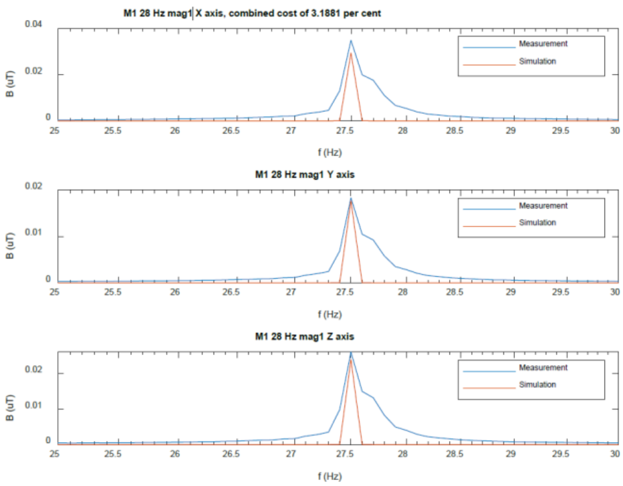

Fig. 3. Steady state motor 1 - 27.5 Hz.

4. Conclusions

This work presents the results of a simple measurement campaign for the identification of main contributors regarding the magnetic behaviour of reaction wheels for CubeSat applications. Moreover, the estimation of the RWA magnetic moment is derived from the results of the measurement campaign with the use of a well-known heuristic algorithm. The knowledge of the magnetic moment can drive an accurate mapping procedure between the produced magnetic field (interference) from the RWA and the "cancelling" source. This will be explored in future work on active mitigation techniques.

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EXPLOITING THE SCATTERING NATURE OF RECONFIGURABLE INTELLIGENT SURFACES FOR B5G/6G NETWORKS

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1. INTRODUCTION

Reconfigurable Intelligent Surfaces (RISs) are expected to be a key enabling physical-layer technology for beyond 5G (B5G) and 6G networks, towards the implementation of a smart radio environment (i.e., by making the wireless environment programmable and controllable). Irrespective of the specific hardware implementation of an RIS, RISs consist of a large number of reflective elements that are capable of manipulating the propagation of incident electromagnetic (EM) waves. In other words, alteration of the channel realization is achieved, a situation that may be quite beneficial for the multifarious use cases envisioned for B5G/6G wireless networks.

From a communication point of view, potential benefits of RISs include:

- Radio coverage enhancement, by creating virtual Line-of-Sight (LOS) links in low coverage areas or dead-zones for outdoor or indoor users.
- Increase of channel capacity, as calculated by the ergodic achievable rate R= E{$\log_2$(1+SINR)}, whereas SINR is the instantaneous Signal-to-Interference plus Noise-Ratio.
- Security enhancement, by worsening the signal detected by eavesdroppers.
- Energy efficiency, mainly due to the nearly-passive operation of RISs.

In essence, aside the (anomalous) reflection capability provided by an RIS, other EM elementary functions may be applied by them on the incident EM wave for communication purposes, as depicted in Figure 1 (see Di Renzo et al. (2020) for more details). However, the great majority of papers in open literature are focused on engineering the diffuse scattering occurring on the RIS, due to the anomalous reflection of the EM wave of interest via the RIS's reflective elements. Furthermore, taking into account the scattering issues related to the propagation medium, it becomes evident that the scattering nature of RIS-aided wireless networks becomes of paramount important when proceeding to their performance evaluation.

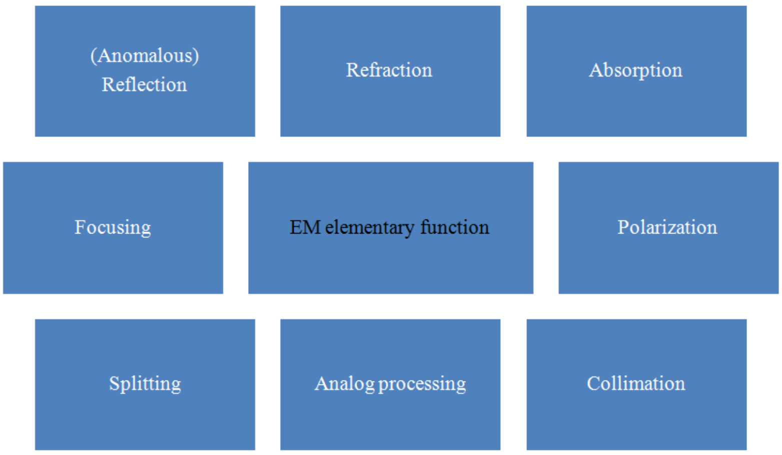

Figure 1. EM-based elementary functions for RISs

In such a framework briefly described above, the aim of the paper is to point out the scattering nature of RIS-aided wireless networks in a qualitative manner, without resorting to complex mathematical analysis. Thus, in Section 2, we interpret an RIS as an array of diffuse scatterers which contribute to the passive beamforming of the incident information bearing EM wave. In Section 3, the scattering issues that may occur across an end-to-end link are commented, in conjunction with some indicative use cases envisaged for the B5G/6G networks. Finally, Section 4 concludes the paper, by pointing to research directions that should account the scattering nature of RIS-aided networks.

2. SCATTERING AND RISs

Two main RIS implementations have been proposed and investigated in the literature: reflectarray-based and metasurface-based implementations. The conceptual block diagram of an N*M reflectarray-based RIS implementation is shown in Figure 2, whereas the dimensions of each reflective element (i.e., Antenna Element-AE) is comparable to the wavelength (e.g.,λ/2) of the incident to the RIS EM wave. The overall RIS is, essentially, a passive reflectarray whose AEs' termination can be controlled electronically through the control circuit board under the supervision of the RIS controller. The aforementioned control of each AE has to do with the phase-shifting of the incident EM wave, which results to backscattering the EM wave to a particular direction. In essence, each AE acts as a diffuse scatterer and the whole RIS implementation is sometimes referred as a "digitally controlled scatterer". Thus, in our case with N*M AEs for the RIS under consideration, the total electric field due to scattering at the desired location (e.g., the location of a mobile user-MU), is as follows:

$$E_{sc}=\sum_{n=1}^{N}\sum_{m=1}^{M}E_{n,m}$$

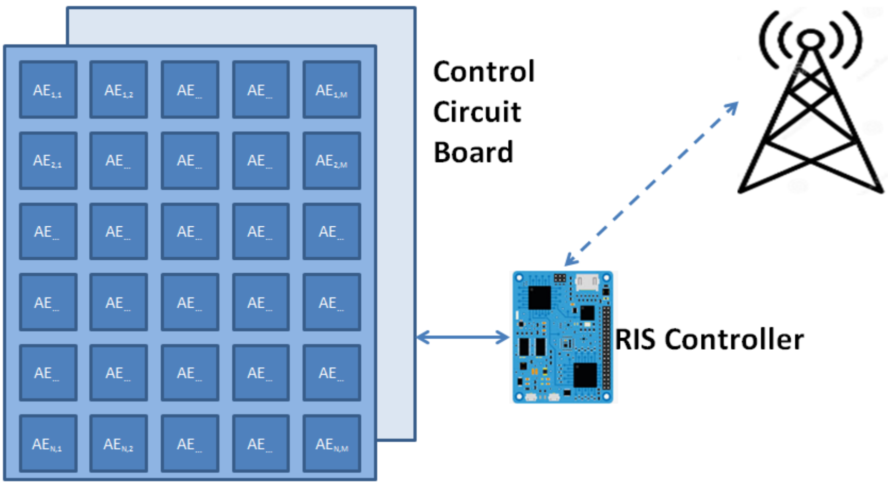

Figure 2. Conceptual diagram of an N*M reflectarray-based RIS with associated control

The second RIS implementation option is based on a metasurface that is comprised of a large number of resonating structures which are closely packed (both their dimensions and the space between them, are much smaller than the wavelength of the incident EM wave). It should be further noted that a metasurface is the 2D form of metamaterials, which are man-made synthetic materials with electromagnetic properties not found in naturally occurring materials. Although the two aforementioned RIS implementations are different and metasurface-based RISs offer increased flexibility (e.g., in terms of phase shifts' granularity), they may be regarded as virtually the same from a scattering point of view.

3. SCATTERING AND E2E TRANSMISSION

Most of prior research on RIS-enhanced wireless networks is based on ideal scattering modelling assumptions. In particular, it is assumed that the RIS scatters the incident EM field towards a single desired direction without generating parasitic scattered waves towards unwanted directions. However, such parasitic diffuse scattering may occur due to design trade-offs, construction inaccuracies, deposit of dust and raindrops on the RIS surface. As it concerns the cascaded Base Station (BS)-RIS-MU channel for end-to-end (e2e) transmission, pure LOS links are assumed (see Figure 3). By adopting, however, such simplifications as in (Ellingson, 2021), the pathloss models derived limit their validity in real-world networks. Thus, going beyond ideal scattering modelling assumptions for the whole BS-RIS-MU channel, a new line of research is proposed in (Basar et al., 2021). More specifically, the authors, by considering the presence of multiple obstacles or reflecting/scattering objects in the BS-RIS-MU channel and integrating RISs into state-of-the-art 5G physical channel models, formulate a baseline cascaded physical channel model for the far-field regime.

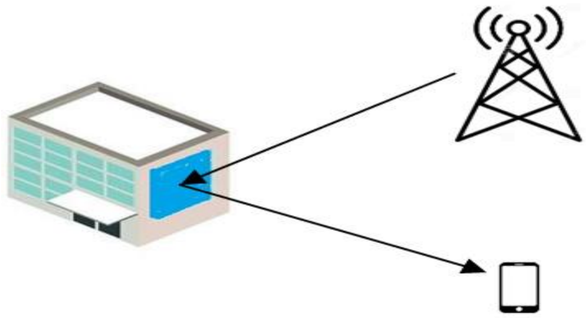

Figure 3. E2E (BS-to-MU) transmission with LOS links

The importance of taking into account the scattering effects of the cascaded BS-RIS-MU channel may be exemplified by the use cases presented here. In Figure 4, a scenario for achieving energy efficiency through minimizing the network power consumption by RIS-aided Multi-access computing (MEC) is depicted, Hua et al. (2020). Thus, especially in case of a rich scattering environment, the aforementioned minimization for the computing tasks that may be performed by multiple BSs, the optimization variables may include the set of tasks for each BS, the transmit power of MUs' devices, and the RIS phase shifts. In Figure 5, for the space-to-ground communications for IoT in a rural area and in order the desired coverage enhancement to be achieved, all relevant scattering effects should be taken into account. The same, also, holds for the use case of Figure 6, whereas higher achievable rates with RIS-equipped UAVs for both the cell-edge and Augmented/Virtual Reality (AR/VR) users, is desirable.

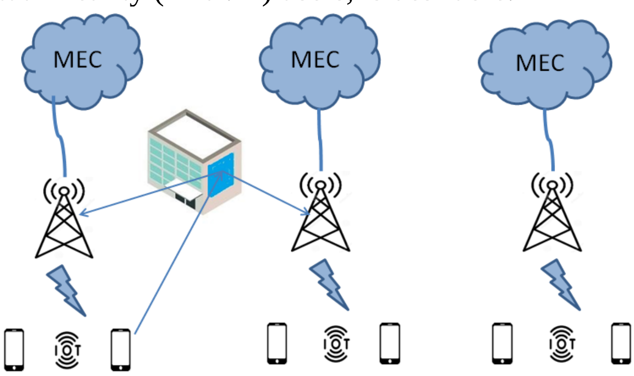

Figure 4. MEC between multiple BSs through RIS

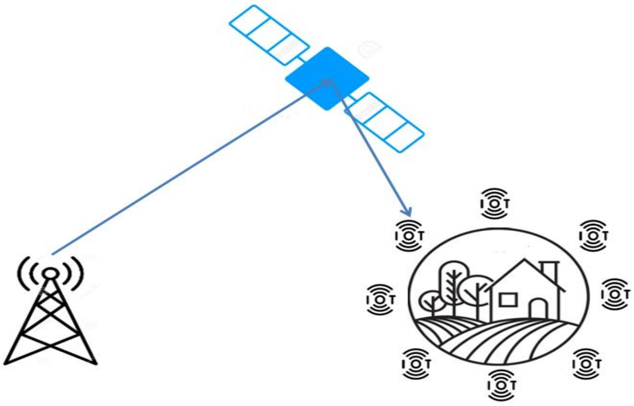

Figure 5. Space-to-ground communications for IoT

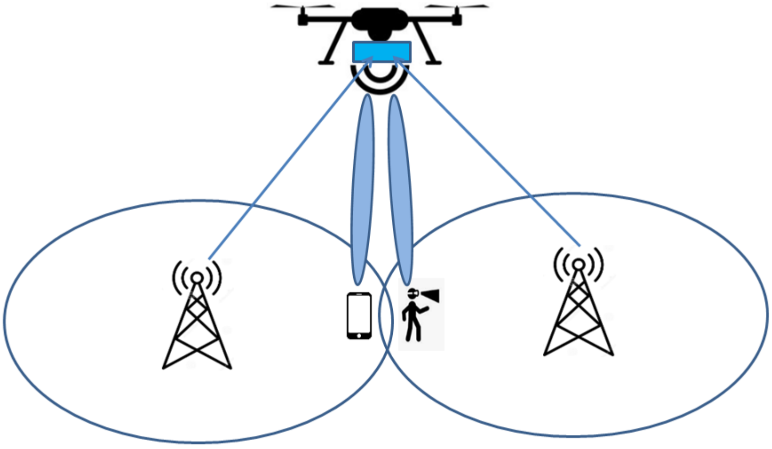

Figure 6. Air-to-ground communications for cell-edge and AR/VR users

4. CONCLUSIONS

The dual scattering nature of RIS-enhanced networks presented in this paper has direct consequences for the analysis, optimization and deployment of future B5G/6G wireless networks. Thus, the adoption of an EM-based framework becomes inevitable and is expected to promote the examination of various theoretical and practical issues related to the overall design and performance evaluation of RIS-enhanced networks. More specifically, the reliable e2e channel modelling of these networks is of primary importance as there exists the need for modelling, not only the attenuation caused by the environmental objects, but also their scattering behaviour. This scattering behaviour is more influential in case of a rich scattering propagation environment, such as in case of dense urban network and indoor deployments. Furthermore, scattered-related issues should be examined correspondingly, as migration to higher frequency bands (such as mmWave, terahertz and optical frequencies) will proceed further and become technologically mature. Moreover, in order the smart radio environment by the exploitation of RISs to be feasible, the dynamics of the communications environment should be taken into account (e.g., for moving users and UAVs).

Other enabling technologies of 6G, such as Artificial Intelligence/Machine learning (AI/ML), may be integrated with RIS operation for optimizing and controlling the reflecting elements (as dictated by the necessity for channel estimation, for instance). More generally, and towards the implementation of the Joint Communication, Sensing, and Computation (JCSC) framework for the 6G, the scattering nature of RIS in conjunction with their high focusing capability in the radiative near-field, may be exploited for beyond communication applications (e.g., radio localization, sensing and wireless power transfer).

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Optimum Wireless Network Management Using Geo-location Big Data

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1. INTRODUCTION

In recent years, and since the introduction of smart mobile devices, global data traffic has grown rapidly over cellular networks. The ever-increasing traffic of the mobile network offers a huge amount of data. The 5G network, its dense heterogeneous architecture with macro -cells and micro-cells, has been explored for flexible ways to balance the network traffic load to improve its spectral efficiency.

The provider of a mobile network must provide radio coverage and sufficient capacity to its subscribers in an optimal way without wasting resources. Therefore the provider must know where their subscribers are and what services they use. Next, it must be aware of network quality problems in order to make the necessary corrections. There are three ways for the provider to know about quality problems i) from the statistics of the network , ii) from the complaints of its subscribers and iii) from the radio-coverage measurements carried out through test-driving with smart phones. The results of the measurements are analyzed with specialized software. The above measurement methods are not efficient because they require a lot of time for a limited number of samples and the utilization of human resources on a large scale. For all the above reasons, it is imperative to exploit Big Data produced by applications, smart phones, etc., so that they contribute significantly to the management of heterogeneous network resources.

Big Data can help improve the quality of service of 5G and next-generation mobile networks. Big Data analysis to process this huge amount of raw data is imperative as useful insights can be extracted. Mobile network operators through Big Data can understand the behavior and requirements of mobile users. They can make a real-time decision (e.g. congestion control and cell mode change – antenna tilt change, etc.) for a wide range of applications. They can also improve network operation and efficiency by properly allocating network resources.

To manage the resources in the heterogeneous network the managers should know the network capacity, the coverage, the number and the locations of the base stations. New resource allocation strategies are needed to meet different traffic demands across the coverage area. One strategy suggested to help mobile network operators make the necessary resource management decisions was the mining of data from the geo-location service.

This article is a literature review on how Big Data and in particular geo-location/mobility data contributes to the optimization of 5G and next-generation networks.The existing geo-location/mobility data mining methods, aims i) to identify radio coverage -quality problems, ii) to determine user positions and iii) to predict services per cell per geographical area. The methods used were methods of clustering, classification and prediction of geographic location and services used by users by region. They were aimed at early warning of network managers, in order to make the necessary decisions for their optimization.

In our work first we present, Big Data and how it contributes to the optimization of wireless networks. Specifically, the process of Big Data analysis is described and the optimization model of wireless networks using big data is presented. Next, the types of geo-location prediction are presented. Then the existing methods of grouping and forecasting geographical areas are analyzed. Clustering methods mainly use machine learning techniques (machine learning without training) and cluster based on density and time. The prediction methods mainly use machine learning techniques (machine learning with training) and their prediction accuracy is determined. Finally, next cell/mobility prediction methods for 5G and next generation wireless networks are analyzed. Mainly machine learning methods (with training or without training) are used for clustering, classification and next cell/mobility prediction.

2. METHODOLOGY

In this article we present the existing geo-location/mobility prediction methods. Statistical analyzes are presented for the performance of the clustering and next geo-location/next cell prediction methods. With analyzing these existing methods, it becomes easier to understand which the most efficient methods for clustering geographic locations are and which have high next geo-location/next cell prediction accuracy.

2.1 Big Data

Big Data refers to data sets that are too large or complex to be handled by traditional data processing application software. The term Big Data, has been used since the 1990s. With the term Big Data refers to data sets with a size that existing software cannot retrieve, manage and process within a tolerable amount of time. The "size" of Big Data constantly changes over time. According to a 2018 definition, a data set is characterized as big data when parallel programming techniques are needed for any operation on them.

As Big Data is rapidly developing in wireless networks, for effective wireless network management, Big Data Analysis is the backbone of wireless communication. Modern data analysis algorithms are applied to manage and extract insights from huge data sources. For Big Data Analysis it is important to provide speeds of processing, sorting and collecting it quickly. The data load on next-generation networks will be significant because services will receive huge amounts of data from a large number of users.

Big data analysis can be interpreted as the process of extracting useful, valuable patterns and hidden information from big data (Rashid et al., 2019).

2.2 Characteristics of Big Data

Big Data has 5V characteristic. The first characteristic is the volume of the data (Volume - is the size of the data). The second characteristic is the variety of data (Variety) and is structured, semi-structured and unstructured data. The third characteristic is the speed of the data (Velocity - massive and continuous flow of data). The fourth characteristic is the value of the data (Variety - Price). The fifth characteristic has to do with the quality and accuracy of the data (Veracity). Due to the different methods of data collection, three other characteristics can be identified: hybridity, complexity and sparseness of data. Because the size of the big data storage system can be expanded quickly we can say that they also have scalability. If the new fields in each element of the collected data can be added or changed easily we can characterize them as extensible.

2.3 Data Management Process

Managing and processing huge amount of data is a challenge to design an efficient and dynamically process-able algorithm. The management and processing of data depends on:

- The data itself: i.e. the volume of data, the variety, the speed, the accuracy, the value.
- The process challenges: data acquisition, data integration, data transformation, choosing the right model for analysis, results;
- Sensor data that requires storage and analysis is growing in volume;
- Improving response time and efficient energy consumption for better network lifetime.
- Data analytics efficiency in a cost-effective and green fashion;
- Covering management challenges such as security, privacy, governance and ethical aspects;
- Redundant data, created in some areas due to mobility or other areas suffer from lack of resources (Rashid et al., 2019).

The process of data management is carried out by the following steps:

i. The acquisition and storage of data: Due to the increase in mobile devices and mobility, acquiring and storing large-scale data is a challenge;
ii. Data mining and cleaning: Relates to extracting and cleaning data from large-scale data. The challenges it faces are identifying a better way to mine and clean big data;
iii. Aggregation and integration of data: This is done to aggregate similar data and integrates it to remove redundancy and repetition (e.g. tweets re-tweets);

iv. Data Analysis and Modeling: The process begins after the data is acquired, stored, mined, cleaned and integrated. It is difficult to extract knowledge information from Big Data that is often unreliable, noisy, heterogeneous and dynamic in nature. The techniques used to extract knowledge are descriptive, predictive and prescriptive analyses. Descriptive analysis mainly uses visualization tools for network performance, traffic profiling, mobility pattern, and measuring key performance indicators (KPIs). Predictive analytics is a valuable tool for making predictions. Predictive analytics can only produce predictions of what could happen. Predictive analysis suggests decision options for Slicing, Virtualization, Edge-computing, Caching and the implications of each decision. Prescriptive analysis is an effective forecasting model. Big Data Analysis requires active data and a feedback system to monitor the results produced by the model;
v. Data interpretation: Extracting knowledge to make appropriate decisions. It is a relatively easy step and can be done with visual representation of data making the data comprehensible to users (Rashid et al., 2019). Figure 1 shows the data management process.

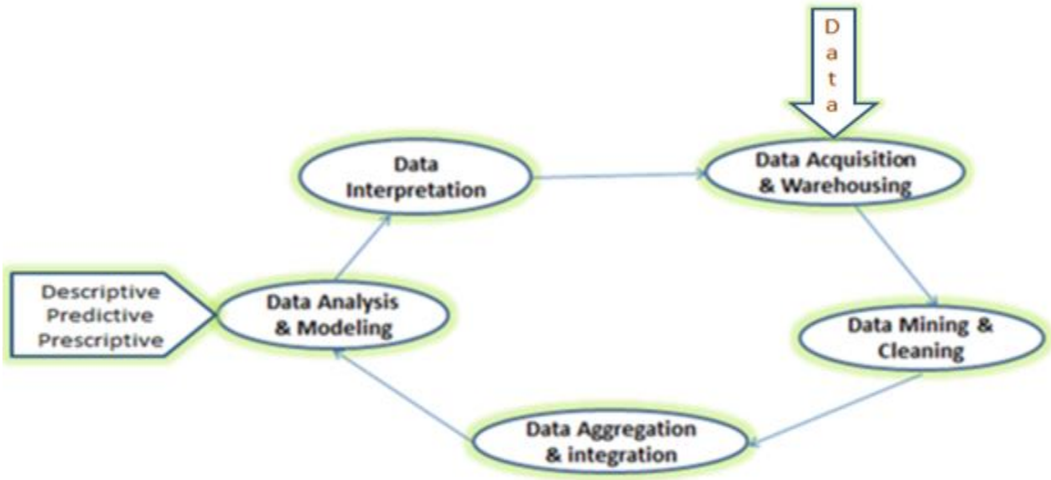

Figure 1. Data management process.

2.4 Types of Big Data

Big Data is divided into two categories into user data and administrator data. User data is related to the user's profile and behavior, and offers information such as their location, mobility and personal communication (behavior/pattern). Admin data comes mainly from CN and RAN. Data in CN provides network performance information, successful calls and usage indicators per application. Data in the RAN provides cell information (e.g. eNB configuration information, resource status information, interference information, handover reports, mobility information, error status, link usage, call drop ratio), signaling messages exchanged between the eNB and EU. (e. g. RRC messages for connection setup and delivery) and radio signal measurements (e.g. reference signal reception strength, reference signal reception quality, etc.) (Zheng, 2016).

2.5 Mobile Network Optimization Framework with Big Data

Mobile network optimization using Big Data includes the following processes:

i. First, the Big Data is collected. The Big Data collection can be achieved by the user equipment's (UE), the radio access network (RAN), the core network (CN) and by the Internet service providers (ISP). Data collection is done through user applications or control signaling. The data is collected in real-time, from multiple sources, heterogeneous and voluminous. In the advanced RAN NodeB (eNB), data is collected both at the cell level (including over-the-air signaling) and in instantaneous measurement reports. Network managers have a huge amount of data related to user carriers/services in the Core Network (CN);

ii. Data storage is managed. Big Data storage infrastructure must have scalable capacity and scalable performance. Storage management must be simple and efficient. Storing and sorting data can be easily achieved;

iii. The data collected and stored are analyzed. To process the data and transform it into knowledge, techniques of data analysis and extracting the knowledge into actionable knowledge are required. Analysis of Big Data is intended to identify problems. Managers will be able to decide what/how to optimize at the appropriate level (e.g., user, cell or service);

iv. Perform network optimization. Optimization measures that can be applied by the control functions at the RAN and at the user level (Adjustment for each user depending on the class of service). They can also predict traffic fluctuations for network and user performance. Figure 2 shows mobile network optimization framework using Big Data (Zheng, 2016).

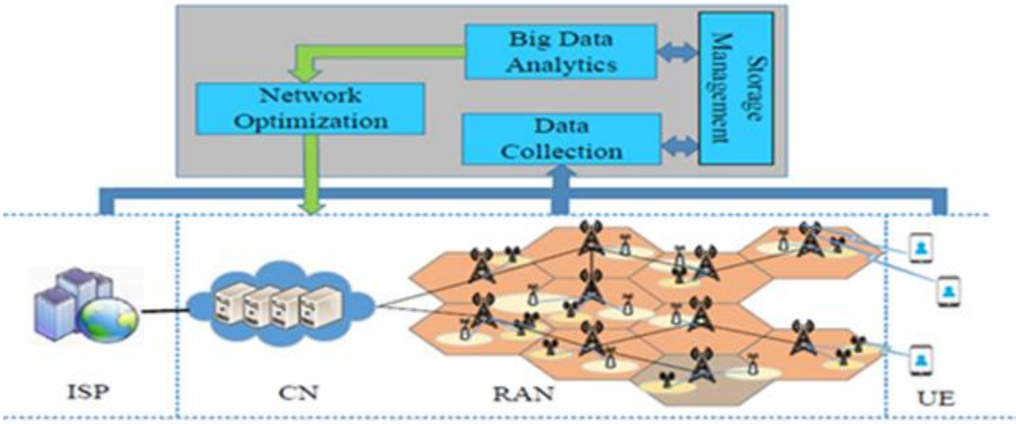

Figure 2. Mobile network optimization framework using Big Data (Zheng, 2016).

2.6 Stages of Wireless Network Optimization through Big Data

In order to optimize Wireless networks, the network should first be properly planned. In most traditional deployment cases, eNB locations are not optimized due to the lack of sufficient statistics. A possible solution is to use data (applications, location information) generated by users and networks. This huge amount of data needs to be processed with advanced analytics techniques to turn it into actionable knowledge. Managers will thus be able to make decisions about where and how to deploy eNBs in networks. It allows them to predict traffic trends and prepare plans for future improvements.

The second stage is resource allocation. Using data analytics, predictions of user behavior and sentiment are made from the generated data. With this predicted information, administrators can allocate more radio resources to the hotshot. So, that the traffic peak is absorbed smoothly without sacrificing the user's QoE. In addition, with the Cloud RAN architecture predictive resource allocation to central baseband units can help accurately serve the right place at the right time. Thus knowing when and where traffic peaks occur, minimal service interruptions are caused.

The third stage is interference coordination. Within a network that has small cells, interference coordination between macro and small cells must be performed in the time domain instead of the frequency domain. It allows efficient allocation of resources between intervening cells and improves load balancing between cells in the network. It allows a macro-cell eNB (MeNB) and its neighboring eNB small cells (SeNBs) to transmit data in separate sub-frames (eICIC). That is, they are kept orthogonal in the time domain, especially avoiding the interference from the MeNB to the SeNB. When communicating with cell-edge UEs, SeNBs use the sub frames that are orthogonal to their neighboring macro-cell. Possible interference from the MeNB is thus avoided. SeNBs can transmit to UEs within their cell center in any sub-frame, regardless of whether the MeNB is carrying data at the time.

A special type of sub-frames is defined for the implementation of the separate sub-frame (eICIC), i.e. the almost empty sub-frame Black Surface (ABS). This sub-frame carries no data but only minimal control information (e.g. the reference signal, mandatory system information, etc.). In this way, interference with data signals is prevented. Interference caused by control signals is mitigated. In an LTE system, a radio frame consists of ten sub- frames. Each of the sub-frames can be used as either a normal sub-frame or an ABS by the eNB except for sub-frames 0 and 5. The decision on how to configure the ABS sub frames is made by the network manager. Determining an appropriate ABS ratio of macro cell to small cells depends on many factors (e.g. service types, traffic load in the given area, etc.) (Zheng, 2016). Figure 3 shows the stages of wireless network optimization from Big Data.

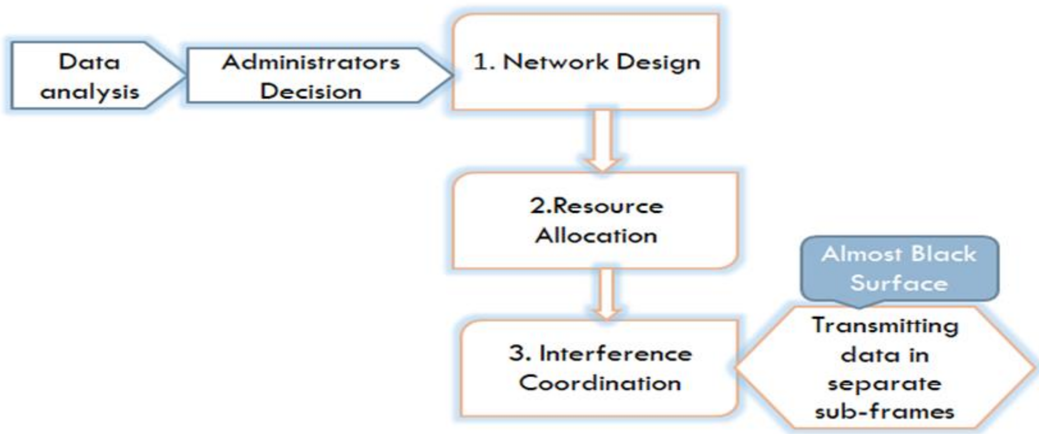

Figure 3: Stages of Wireless Network Optimization from Big Data.

2.7 Barriers to the usefulness of Big Data

Mobile battery drain, location errors, and environmental interference hinder the usefulness of Big Data. These results of data cannot be collected at certain times. By developing data mining, filtering and extraction techniques, junk data can be eliminated. Dynamic multi-source data mining is a promising solution for mining heterogeneous data.

2.8 Geo-location

Geo-location is the process of determining or estimating the geographic location of an object. Geo-location returns a set of geographic coordinates (latitude and longitude) on a map. For each geographic location, the data record includes its geographic coordinates and time stamp. Geo-location uses various optical and electronic methods, including position lines, position circles, celestial navigation, radio navigation, and the use of satellite navigation systems. The calculation requires measurements or observations of distances or angles to reference points whose positions are known. In two-dimensional surveys, observations of three reference points are sufficient to calculate a position in a two-dimensional plane. In practice, observations are subject to errors arising from various physical and atmospheric factors that affect the measurement of distances and angles (Wikipedia, 2022).

Today, many services based on geo -location (GBS) have emerged using smart mobile devices. Massive geographic data, vehicle trajectory and geographic location records are generated daily and have been named mobility big data (MBD) (Xu , 2017). Mobility big data refers to geo-location data generated and collected by smart mobile devices when people are on the move.

Traffic forecasting plays an important role in improving network quality and energy saving of mobile networks. Long-term traffic forecasting can provide a detailed pattern of future traffic and allows more time for planning and optimization. Most of the motion prediction models use motion history, i.e. they make predictions based on historical timestamp data. Geo-location Prediction (GP) can be applied to Geo-location Based Services (GBS). These predictions will be able to provide future services for application users. Much research has been conducted to improve mobility management in fifth generation wireless communications using a wide variety of methods.

Big mobility data consists of:

- The sets of moving objects (e.g. five mobile phones);
- The observation time of the data (e.g. 10 days);
- Geo-location data records to keep track of where each object has passed.

2.9 Types of mobility data

Mobility can be divided into three categories of data according to (Xu , 2017). The first category is the Global Positioning System (GPS). This data is collected via satellite-based location. The second category is the global system for mobile data communications (GSM). GSM Data is mainly collected through the tracking of the mobile phone users by the mobile phone stations and received by the network operators. The third category is wireless fidelity data (Wi-Fi).

GPS data can be represented with latitude and longitude coordinates and time stamps (Points = (lat, longti, time)). Changing the user's geographic location can be displayed with a series of coordinate points (latitude, longitude) that are unique. The raw data is pre-processed with clustering algorithms (divisive, density-based, time-based clustering).Polygonal and circular shaped popular areas are rendered. Its drawback is that coordinates cannot be recorded in closed spaces. This results in the data not being as accurate as their prediction.

GSM data locates mobile phone users through cellular stations. Data information is obtained from administrators. Administrators cannot disclose geo-location information. Mobile stations can locate a user through multiple stations at the same time. This fact affects the accuracy of the geographic location.

Wi-Fi data can be obtained through the fingerprint method by detecting a wireless signal in the environment. While users are stationary, the beacon in the environment will record the response rate as a fingerprint of that location. Then judge whether the user is in the same geographical location as the fingerprint recognition. Wi-Fi data can only be obtained in places where the wireless signal is strong. In places like outdoors or streets, this is not realistic because of the lack of Wi-Fi access points and because the WI-FI signal is unstable. The data of weak Wi-Fi signal is not useful.

2.10 Mobility Big Data collection methods

The methods of collecting big mobility data can be divided into categories based on each system that collects the data. These categories are satellite-based collection, geographic information system location-based collection, wireless network location-based collection, and sensor-based collection. As can be seen, the collection methods take the corresponding name depending on the different types of data collected (Xu, 2017). Table 1 shows the methods of collecting big mobility data.

Table 1: Big Data Collection Methods Mobility

Collection Methods	Tools
Satellite Positioning System	Satellites
Geo-information System	Gps
Sensor	Accelerometer, Gyro, Electronic Compass, Mobile Camera
Wireless Coverage	Wi-Fi , bluetooth, Gsm Signal, Wireless Single , RFID

2.11 Geographic location prediction

The popular geo-location area (Popular Geo-location Region-PGR) refers to a regional geographic location grouped by a series of initial data points. The time interval and the distance of the start point and the end point have a certain limit. The personal trajectory (Personal Trajectory - PT) is a sequence set of popular geo-locating sites sorted by time sequence (PT = {home, office, home}) (Xu, 2017).

Geo-location prediction can be divided into two main parts. The first step in preprocessing geo-location data when building a geo-location prediction model (GPM) is the popular mining geo-location region (MPGR). The second step in building a geo -location prediction model is mining personal trajectory (MPT) (Xu, 2017).

To mine a popular geographic location region (MPGR), we cannot directly mine information because the user's geographic location information data on the map is continuous or discrete points. These points should be aggregated, mining the popular geo-location areas that have a high correlation with the user (e.g. home, workplace) (Xu, 2017).

For Personal Trajectory (MPT) mining, the originally collected geo-location data of the user is analyzed, frequent moving trajectories of users are mined. The user's moving trajectory model is established. The rule of the user's geo -locating region in space and time is presented. A geo-location prediction model with an effective information organization model is provided (Xu, 2017).

The prediction of geographical position is done in three phases. In the first phase, a popular geo-location area is mined to pre-process raw geo-location data collected from smart mobile devices. In the second phase, personal trajectory information consisting of popular geo-location areas that are results of the first step is mined. In the third phase, a geographic location prediction model is created.

The geo-location prediction model system is a client/server (C/S) model. Geo-location data is initially collected through software installed on smart phones or terminals and stored in a database on a server. The geo-location data is then pre-processed in 2 phases:

i. Geo-location hotspot mining needs raw geo-location data as input, and then uses the systemization algorithm to process and get the most relevant location data as output.
ii. Mining a personal trajectory takes the results of the second step as input and builds the user trajectory according to the time sequence as output. The results of this step can be used by the geographic location prediction model as input data or used in the anomalous trajectory detection in the security domain as data support. The results of the previous steps are used to create a geographic location prediction model through different algorithms/methods (Xu, 2017). Figure 4 shows the geographic location prediction model system.

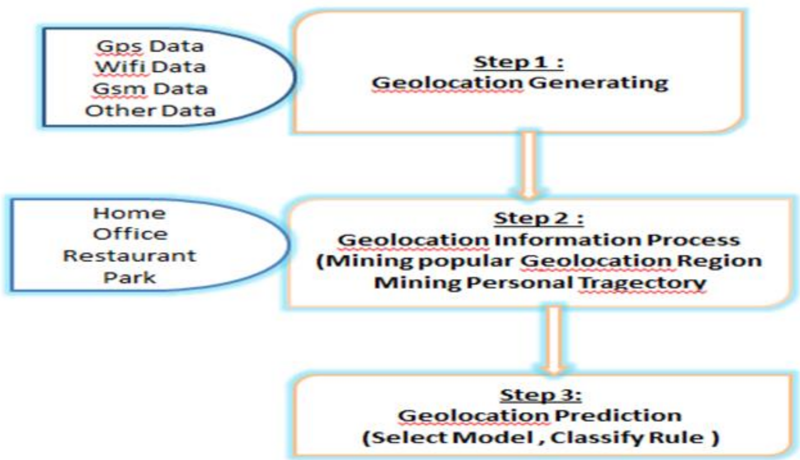

Figure 4. Geo-location Prediction Model System.

2.12 Existing research in geographic location prediction

Geo-location prediction that is based on big mobility data is important for improving the management of 5G and next generation networks. According to (Guo, 2014), big mobility data consists of the sets of moving objects (e.g. five mobile phones), the observation time of the datasets (e.g. 10 days) and the geo-location data files for the keeping track of where each object has passed.

An experiment done by Nokia 's research center in 2012 collected data (geographical location, call logs, SMS logs) for 9 months, from 100 students using smart phones. The result was to greatly improve the accuracy of the data set by adding useful information to it (Xu, 2017).

Microsoft Research Asia created the Geo-Life project where it recorded GPS data of 182 volunteers from 2007 to 2012. The project recorded the GPS coordinates of each user from 1 to 5 seconds and for 5 to 10 meters, for any situation (when they were stopped, when they were traveling, when they were walking, etc.). This project helped to improve the quality of raw GPS data (Xu, 2017).

Ashbrook et al. (2003) proposed a K- Means clustering algorithm for mining popular geo-location regions. The disadvantages of this algorithm are that the number of clusters should be set during programming and it has a low silhouette score due to extreme points.

Kangs et al. (2005) solved the shortcomings of a K- Means clustering algorithm by using a time-based clustering algorithm. They first grouped the GPS data based on timeline. Then he would set a time limit and a new point. If there was a time interval between this new coordinate point and the original cluster that exceeded this limit, the new point was defined as a new cluster. This method can automatically discover the number of clusters and filter out trivial points of trajectory coordinates, but it forms an excessive number of new clusters.

Zhou et al. (2007) to avoid the excessive number of new clusters of the method proposed above, they applied a density-based clustering algorithm. In this particular method there are two thresholds in their methods D-limit and Min-Pts. D-limit represents the distance threshold used to calculate the neighborhood of the current coordinate point A. If the distance between A and another coordinate point B is less than D-limit, B is a neighboring point of A. Min-Pts is the limit of the minimum neighborhood number of A. When the neighborhood point number of A is greater than Min-Pts, it will be marked as a new cluster, otherwise A will be marked as an invalid point. This method flags some sparse density coordinate points as invalid data and produces a false positive.

Liu et al. (2013) proposed a grid-based method (to reduce computational complexity) for mining popular geo-location regions. They first divide the moving space of moving objects into a number of non-overlapping cells. They then calculate the continuous trajectory of the moving objects and mark all the cells that these objects have passed. By keeping the times of each cell that has passed, the density of each cell is measured. Finally, they use the filtering strategy refining to search for all high-density cells as popular geo-location areas. The above strategy is a general method for completing a computationally intensive task as quickly as possible. It removes a significant portion of the irrelevant data in a computationally efficient manner. The accuracy rate of the algorithm is 99.3% for covering the trajectory of moving objects and 40.9% for spatial coverage accuracy.

According to Ashbrook et al. (2003), Marmasse defined an interior space through the following method. When the GPS signal disappears, the radius of a circle is considered as an area and treated as interior space if the GPS signal reappears in that area. Ashbrook et al. (2003) added the time factor based on Marmasse method. If the GPS signal reappears within a period of time, such as 10 minutes, that area can be considered indoor. This method has greatly reduced false positives and can be very effective when compensating for data loss due to indoor GPS signal loss.

Long et al. (2011) created a model called Jyotish. The main purpose of the Jyotish model is to extract the popular geo -location areas, from Wi-Fi / Bluetooth data, as well as the time spent in each area. In the end it predicts the next person the user will meet in those areas.

Xiaos et al. (2015) used a regression-based method (RBM) to predict a user's geographic location. In this method the geographical location of the user and the time are the input data. The input data can be represented by a triple D = (lat, long, time) (latitude, longitude, time). The corresponding regression function model is created based on the input data and the maximum likelihood for the regression function is determined. The time of the geographic location that needs to be predicted is entered and the output result is the geo-location of that time node. With this method, geographic locations can only be predicted for a very short period of time. The accuracy of this method ranges from 39 % to 57 %.

Another method for geographic location prediction that was proposed was the Markov method. In this method, a user's moving trajectory, represented by nodes and edges, is taken as input. Then the relationship of the nodes is denoted by a probability matrix according to the k-order Markov prediction. Each edge represents the transition probability of the nodes it is connected to. A tree of transition probabilities is then created. Prediction results can be found in this tree with tree search algorithms. First, the maximum transition probability is found using a traversal algorithm. Prediction results are the next node in the selectable trajectory. The accuracy of this method ranges from 52 %-69 %. The defects of the method are the following: The balance between the complexity of the algorithm and the rate of correct prediction. The effect of time is ignored. Finally, the internal connection of a moving orbit is ignored (Kim et al, 2014), (Herder et al ., 2014).

McInerneys et al. (2013) used the Bayesian method Network - Based Methods (BNM) for predicting a user's geographic location. First, the raw geo-location data is converted into position and time coordinate variables. Then, a part of the data is removed as a training data set. Then, the relationship of the data variables is simplified by assuming that the conditions are independent. Next, the relationship between Parents (xi) and xi is simplified to naive Bayesian Theory (NBT). It then confirms the interdependent parameters according to a joint probability density equation after constructing a directed acyclic graph (DAG) through the interdependent relationship between variables. It then calculates the dependence of a Bayesian model (BM) according to the transition probability equation between two adjacent times. Creates a dynamic Bayes network (DBN) by connecting local Bayes networks at different times. Finally, the probability of a target required to be predicted according to the condition is obtained. Prediction accuracy ranges between 58%-75%.

Bui et al. (2015) used the neural network-based method (NNM) to predict a user's geographic location. First they store historical data in moving object databases (MODs). Then they transform the real-world location prediction with an artificial neural network (ANN) piecewise prediction. This model can predict the later s nodes through the earlier m nodes as the input of the track sequence predictor. Each track order predictor is a neuron in the artificial neural network. Prediction accuracy ranges between 48%-78%.Table 2 shows some popular area forecast surveys. Table 3 presents the methods of grouping geographic areas. Table 4 presents the method of predicting geographic areas.

Table 2: Forecast Surveys of popular Areas.

Model	Results
Geolife (2012)	Improving the quality of raw GPS data
Jyotish Model (Ashbrook et al.,2003)	The mining of popular geo-location areas and the time spent in each area. In the end it predicts the next person the user will meet in those areas.
Nokia research center experiment(2012) (geolocation, call logs, SMS logs)	Greatly improved the accuracy of the dataset by artificially adding useful information's.

Table 3: Geographic Area Clustering Methods.

Method	Results	Disadvantages
K-Means (Ashbrook et al., 2003)	Mining popular geo-location areas by data clustering	The number of clusters must be set. Very low Silhouette score because of outlier points
Time-based clustering algorithm (Kang et al., 2005).	This method can automatically discover the number of clusters and filter out trivial track coordinate points	Forms a large number of clusters
Density-based clustering algorithm	This method avoid excessive number of new clusters.	Flags density coordinate points as invalid data and produces a false positive.
Marmasse Method + Time period (Ashbrook et al., 2003)	This method has greatly reduced false positives and can be very effective when compensating for data loss due to indoor GPS signal loss.	-

Table 4: Methods of Forecasting Geographic Areas.

Method	Accuracy	Disadvantages
Grid-based method + Filtering - refining strategy (Liu, et al., 2013)	40.9% for spatial coverage rate 99.3% for moving objects.	-
Bayesian Network Method (BNM) (McInerney et al., 2013).	58%-75%	Complex steps, complicated computing and poor scalability.
Neural network Method (Bui et al., 2015)	48%-78%.	High algorithm complexity, need a large number of training data unstable prediction accuracy, hard to use and understand
Markov Method (Kim et al., 2014), (Herder et al., 2014)	52%- 69%	High algorithm complexity, ignoring the impact of time, ignoring the inner connection of moving trajectory.

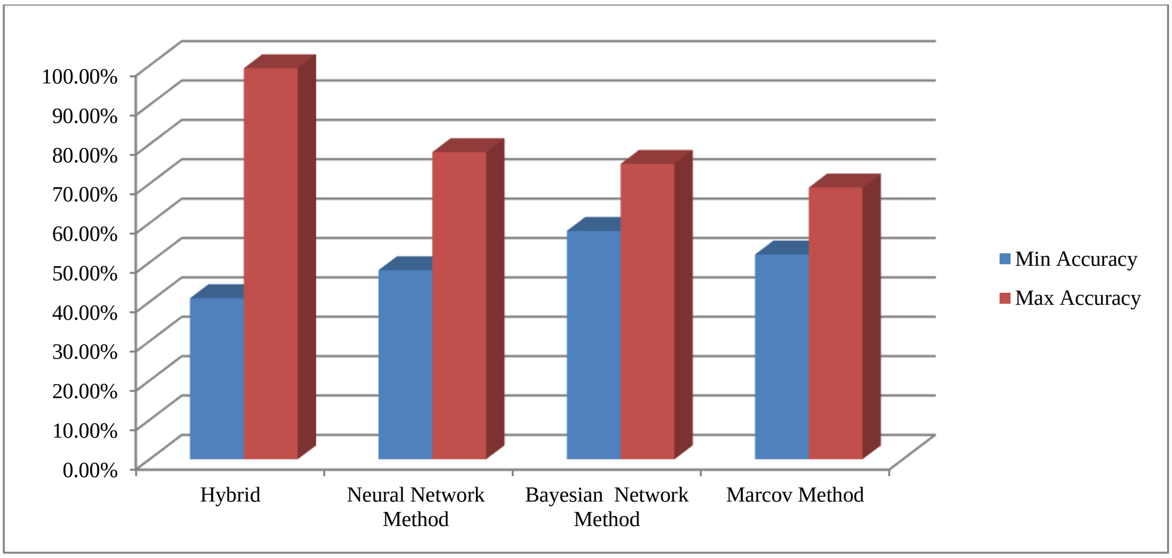

Figure 5: Geographic Area Prediction Accuracy.

2.13 Researches on wireless network optimization using geo-location data

Zhengs et al. (2016) presented the motion load of several typical applications, e.g. WeChat, news and online music services in 3 urban areas: business, restaurant and residential zones. Data are collected at various times every day for a week in a large city in northeastern China. First the authors after receiving the data used machine learning techniques to mine the data and create a user profile (user preferences, habits and interests.). The techniques used were Support Vector Machine (SVM) and Restricted Boltzmann Machines (RBMs) to classify the data. Classification of data helped administrators to deploy cache servers in the RAN. In the end, a machine learning engine using an artificial neural network is used to create the relationship that affects the QoE of the users. In this article the final conclusion was that Big Data analysis can increase network efficiency and reduce deployment costs.

Le et al. (2018) first built a model to analyze the relationship of next-hour GSM traffic of a specific cell with observed KPIs, using Naïve Bayes. The model includes 10 nodes—one target node and 9 observation nodes. The target node represents the next hour's movement to be predicted and the observation nodes represent the current hour's KPIs and the previous movement. The same was repeated for the same cell for voice mobility (cs) and data mobility (ps). They then used machine learning techniques to predict motion (GSM) for 2 specific cells. The techniques used were Auto algorithms Regressive (AR), neural networks (NN) and the Gaussian process (GP). The proposed model is flexible enough to handle with high accuracy different patterns, characteristics and time-scale behaviors.

Arvinte et al. (2019) introduced a machine learning approach to solve the beam-handling problem through geo-location information in a non-autonomous (NSA) 5G-NR mm-Wave system. Two types of support vector machines (SVMs) were trained that take users' geographic locations as input. The solution is based on a decentralized SVM model per gNB used to predict the best beam index in terms of SNR and SINR. A new multi-user scheduling algorithm was also proposed and takes as input the beam/cell correlations based on user geo-locations provided by SVMs. In this context, the multi-user scheduler performs interference avoidance using a sliding window approach and maintaining a list of forbidden beams. The proposed model achieves a significant latency reduction of up to 38%, increases the maximum supported user speed, and reduces the total resource burden by at least 8% - 11%. The accuracy of this method reached 90% for the training of 50% of the spatial points.

Sardar et al. (2010) used a GPS framework that calculated the distance between two points using the Haversine formula and set a threshold G at 50% of the antenna range, to predict the next cell. This method minimizes the handoff delay in Layer 2 and Layer 3, but the initialization phase delay was 60ms due to GPS response time. GPS has an error of 10m which affects the accuracy of the forecast in the high coverage cells. The base station does not allow switching between internal and external geo-location systems.

Saleh (2016) proposed a Hybrid Mobility Prediction (HMP) strategy. This method combines probabilistic predictor (PP), group-based prediction (GP) and spatial predictor (SP). PP uses the algorithm Naïve Bayes. GP uses the ant colony optimization (ACO-optimal path finding) algorithm. SP tries to detect the topological architecture of the current recording area to improve the prediction process. HMP provides accurate prediction of the next cell, but increases the computational cost. The proposed model has the advantages of handling all the computational process while the MS is offline. This benefits energy savings and does not add additional calculations.

Abdalla et al (2019) used a hybrid EHP model to predict the location of the next cell. Geo -location data (start time, longitude, latitude) are taken from 4 GPS for three groups of users in UTM. The groups are undergraduates, postgraduates and staff, reflecting a diversity in ages, activities and mobility patterns. The exact location of the user's mobile is the intersection of the 4 signals from the 4 GPS. The proposed model combines random and regular behavior. Initially the basic Markov prediction is used which collects the basic information for the prediction. This will be used in the enhanced predictor after adding the behavioral feature. The time series forecasting model is then used to capture the short-term movement behavior for insufficient history. This creates models through historical analysis and using them to make observations and guide future strategic decision-making. When the user's mobile has no history or the failure prediction occurs due to random movements of the mobile the prediction is made either by probabilistic prediction or by time series prediction. The parameters (latitude (X), longitude (Y) and ellipsoidal height (Z)) are calculated in order to find the current position and direction and speed of the mobile phone. The accuracy of next cell prediction for the proposed method is 85%.

Shekhars et al. (2021) used geo-location data from the South app African Taxi Rank Location and used geographic location clustering techniques to optimize 6G networks based on mobile base stations using UAVs. First, the k-means clustering algorithm was applied to the data set to obtain baseline results. K - Means requires the number of clusters to be determined in advance which leads to problems with real-time resource allocation for base stations. To overcome this problem, an iterative approach was taken in the code. All cluster values from 1 to 100 were used and the corresponding silhouette scores were calculated for all cluster values. The cluster value with the highest silhouette score (a method of interpreting and validating consistency within groups of data) was defined as the final result. Then the DBSCAN technique was used. It is a more improved algorithm than the original one due to the density based mechanism. Another important difference with DBSCAN is that it has the ability to distinguish outliers as separate entities. This results in better performance since the extremes are separated and a higher silhouette score is achieved. Implementation of DBSCAN algorithm was done by first ignoring the outliers and then treating the outliers as unique clusters. Then the HDBSCAN algorithm was used like the DBSCAN algorithm. In the end a hybrid clustering model was used initially the HDBSCAN algorithm was used. The dataset is then split into clustered points and outliers resulting from HDBSCAN. The clustered points were then used as training data to train a K- Nearest Neighbors (KNN) classifier and allocate each extreme value to the nearest cluster. In this way, the endpoints are integrated into the groups giving each user equipment the appropriate network coverage.

Figure 6 shows the clusters of each presented clustering method and figure 7 shows their silhouette scores. Table 5 shows all the presented wireless network optimization methods using Big Data. Figure 8, shows the geographic area prediction accuracy for each method.

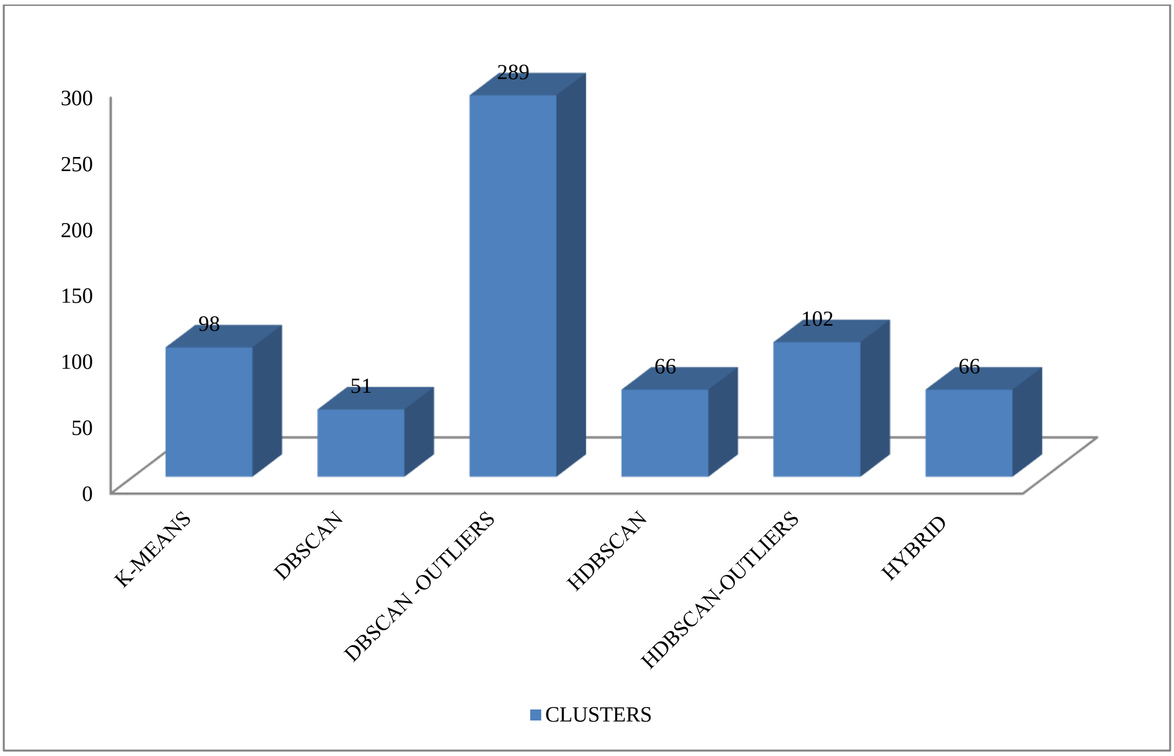

Figure 6: Clusters by Clustering Method.

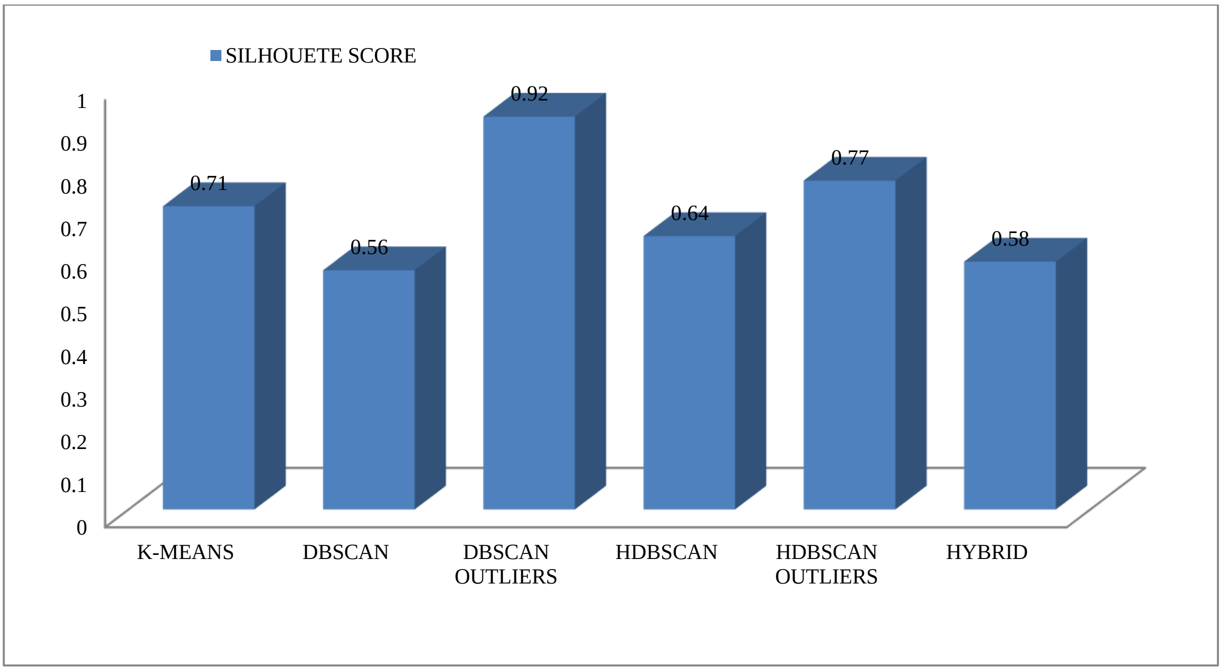

Figure 7: Silhouette Scores of Clustering Methods.

Table 5. Wireless Network Optimization Methods Using Big Data.

Method	Purpose	Results
i. Support Vector Machine (SVM), Restricted Boltzmann Machines (RBMs); ii. Artificial Neural Network (to create the relationship that affects the QoE of the users) (Zheng et al., 2016)	i. For classification of the data to help administrators to deploy cache servers in the RAN; ii. To create the relationship that affects the QoE of the users.	Big Data analysis can increase network efficiency and reduce development costs.
i. Naïve Bayes (classification); ii. Auto Regressive (AR), Artificial Neural Network (ANN), Gaussian process (GP) (Le et al., 2018)	i. To analyze the relationship of next-hour GSM traffic of cell a specific with the observed KPIs; ii. Traffic prediction (GSM) for two specific cells.	It handles with high precision, different time scale patterns, characteristics and behaviors.
i. Support Vector Machines ; + ii. Sliding Windows Approach (Arvinte et al., 2019)	i. Was used to predict the best beam index in terms of SNR and SINR; ii. Was used to prevent interference by maintaining a list of prohibited bundles.	Up to 38% latency reduction. Increases the maximum supported user speed. Reduces overall resource overhead by at least 8% - 11%. The accuracy of this method reached 90% for the training of 50% of the spatial points.
Haversine type + G limit was set at 50% of the antenna range (Sarddar, D. et al., 2010)	For predicting the next cell from Gps data.	This method minimizes the handover delay in Layer 2 and Layer 3, but the initialization was 60ms delay.
i. Naïve Bayes (PP); + ii. Ant Colony Optimization (GP); + iii. Spatial Predictor (SP) (Saleh ,2016)	i. Is the Potential Prognostic Factor. ii. Is the Group-based Prediction iii. Tries to detect the topological architecture of the current recording area to improve the prediction process.	Provides accurate prediction of the next cell, but increases the compute process.
i. Markov ; + ii. Tıme Series Forecasting Model; (Abdalla et al., 2019)	i. Is used to predict the location of the next cell. ii. Is used to capture the short-term movement behavior.	Predict the location of the next cell with accuracy 85%.
i. K-means ; i. DBSCAN; ii. HDBSCAN; iii. HDBSCAN+ K NEAREST NEIGHBOURS; (Shekhar et al.,2021)	i. Is for clustering. ii. iii. iv. Are used for clustering due to the density-based mechanism.	For clustering geo-location information

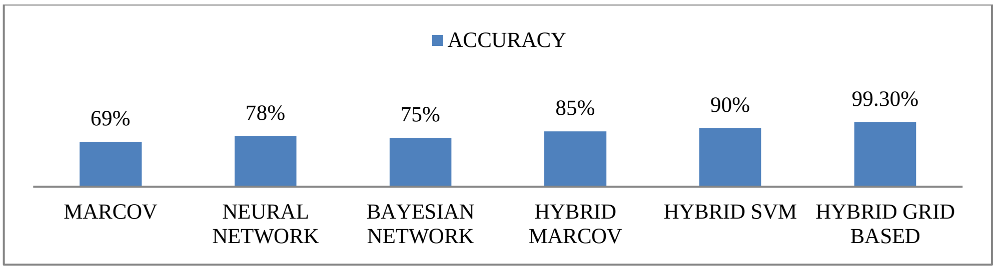

Figure 8: Geographic Area Prediction Accuracy.

3. RESULTS AND DISCUSSION

For the presented geo-location clustering methods, as we can see from table 3, when simple clustering methods are used, several problems are presented. The Marmasse method combined with the definition of a time period method minimizes the clustering problems.

For the geo-location prediction methods, according to figure 5 it is observed that the hybrid method (Grid-based method + Filtering - refining strategy) has quite high accuracy in predicting the geographic location of moving objects, compared to all other methods, however it has very low spatial coverage accuracy. It can also be observed that the accuracy of the prediction of the neural networks is either quite low or quite high (instability of accuracy), in relation to the Bayesian method Network Method and Markov Method that the lowest accuracy values are close to the highest accuracy values. The low and high precision value of each method depends on the amount of sample. When the amount of the sample is large, it reaches the highest value of geographic location prediction accuracy. Of the three basic methods (Neural network, Bayesian Network, Markov Method), the Bayesian Network Method has the highest average accuracy value at 66.5%. Neural Network method is the next with an average accuracy value of 63% and lastly Markov Method with 60.5%.

For optimization of wireless network, various methods have been proposed for classification, clustering and motion prediction-next cell prediction. Each model used depends on the particular problem to be solved. For the clustering methods, according to figures 6,7 we can see that DBSCAN clustering with clustering extreme points has the most clusters with a very high silhouette score (0.9) than all other clustering methods. For the next cell prediction methods, as we can see in figure 8, can be observed that for the prediction of the geographical position - next cell the use of hybrid methods have an increase in the prediction accuracy ranging from 85%-99.3% in relation to basic methods. More specifically, the hybrid Markov method increased the accuracy compared to the Markov method by 16%.

4. CONCLUSION

This paper presented existing location and mobility prediction methods for the optimization of 5G and next generation wireless networks. For the optimization of 5G and next-generation networks, the presented methods involved geo-location and mobility data mining. These methods were used for clustering, classification and location-mobility prediction. The differences of the clustering methods have to do with how each method deals with outliers that affect the calculation of the silhouette score. For this reason more research is needed for more flexible and more efficient clustering algorithms. In the existing prediction methods, the prediction accuracy is quite high, but they need further improvements to increase their accuracy and reduce the complexity of the algorithms. It was also observed that the use of hybrid forecasting methods increases the accuracy of the original forecasting methods. As future work, a hybrid model can be designed for location prediction using machine learning techniques combined with genetic algorithms (e.g., genetic algorithms and artificial neural networks). In addition, the geo-location service will be able to consider the possibility of mining data (e.g. drop call rate , interference detection, data throughput , latency) in order to optimize 5G and next generation networks.

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High Performance Computing at Several Scales: From the EU Initiative to Edge Computing

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1. INTRODUCTION

The High Performance Computing (HPC) designation has been around for several years[1]. It was initially related to the field of supercomputers but now extends to a very broad set of computing devices. The set of applications and programming tools that were restricted to some computer systems with a very limited public access have become widely available at several computing scales. Major developments in common processor architectures broadened the field of application of HPC. Processors with multiple cores, although available before, saw in 2001 the first true multi-core processor, released by IBM under their Power4 architecture and geared towards workstation and server applications. In 2005, however, Intel released its first consumer focused dual-core processor which was a multi-core design and later that same year, AMD released their version with the Athlon X2 architecture. Nowadays almost every processor design is multicore ranging from the fastest CPUs to the least power hungry such as those found in typical Internet of Things (IoT) architectures. Graphical Processor Units (GPUs) also became multicore and NVIDIA released its first Common Unified Device Architecture (CUDA) release in the 23rd of June 2007. This was a major breaktrough in terms of HPC for low cost systems since most HPC applications could improve the computational performance by some orders of magnitude with a much lower financial investment.

A large number of approaches and technologies can be found in the realm of HPC: super computer systems administration; very high speed networking; highest levels of Cybersecurity; parallel programming; computer simulation; advanced scientific computing, etc..

The paper presents an integrated overview on the HPC area but mainly restricted to the availability of systems and programming tools at several implementation scales. It presents an overview of the European Community efforts to advance the supercomputer area in several directions and lists some of current deployed systems under the Joint EU initiative. The connection between small scale HPC, at the edge computing systems, and the current top level supercomputer systems, is made looking at the common software used to program these systems. Although the performance levels are radically different the tools are basically the same and can be used to greatly improve the execution times of many applications.

The paper starts in Section 1 with an introduction to theme of HPC, namely some of the most common definitions and main applications; the list of contributions of the paper and this short overview of the structure of the document.

Afterwards, in Section 2, the types of computer systems where HPC is found, at several computing scales, are enumerated. The subject starts with the presentation of the Joint EU HPC initiative, presents the current TOP 500 european supercomputers and their ranking. It proceeds to present typical HPC applications. It finishes with a discussion on the HPC at the edge computing level.

Section 3 is devoted to different programming models and the corresponding implementations and programming languages. The message passing and shared memory approaches are briefly presented and also the library vs. directive based programming models are discussed.

An example of an image processing application where the application of HPC concepts are

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1 Some sources refer to the term being equivalent to supercomputing thus dating it to 1978. A short history is presented in https://hpc.netl.doe.gov/about/history-of-hpc/index.html.

demonstrated is presented in Section 4. The execution times of this application: an iterative noise reduction procedure, can be vastly improved by programming with HPC technologies, namely OpenCL.

The paper concludes with Section 5, with a set of main results and future work.

2. TYPES OF HPC SYSTEMS AND APPLICATIONS

A classical set of high performance computing fields of applications, compiled by IBM, a major supercomputer supplier since the 1960's, with the corresponding examples, is presented in Table 1.

Table 1: Typical high performance computing fields of application and examples.

field of application	examples
Automotive and aerospace	Computational fluid dynamics modeling; Finite element analysis of impact and structural strength; Computer aided design and machining
Banking, financial services markets and insurance	Monte Carlo simulations; Risk analysis; Fraud detection
Electronics design automation (EDA)	Chip design and optimization; Circuit simulation and verification; manufacturing optimization
Film, media and gaming	Rendering; Computer-aided graphics; Computer-generated images (CGI); Transcoding and encoding; Real-time image analysis and processing
Government and defense	Intelligence agency; Fraud analysis; Climate modeling; Weather forecasting; Energy; Nuclear stewardship; Exploration
Life sciences	Genomic processing and sequencing; Pharmaceutical design; Molecular modeling and biology simulation; Protein docking
Oil and gas	Seismic data processing; Reservoir simulation and modeling; Geospatial analytics; Terrain and topology mapping; Wind simulation
Retail	Inventory analysis; Logistics and supply chain optimization; Sentiment analysis; Marketing offers

(What is HPC? Introduction to high-performance computing, https://www.ibm.com/topics/hpc, 13/092022)

The massive deployment of sensors under the IoT approach, is leading to very large data sets and an increased need for high performance computing. High Performance Data Analytics (HPDA) is one of the areas where recent research using HPC has seen a booming increase (applications in Table 2).

Table 2: High Performance Data Analytics research areas and examples.

research areas	examples
Graph Analytics	Big Data Benchmarking Suite for Cybersecurity Analytics;Graph Query Language;Performance Modeling on Property Graphs;Resilient Message Passing Interface for Fault-tolerant Runtimes; Semantic Data Analysis; Simulation of Large-scale NetFlow Data with Botnet Activity;Topological Data Modeling Web-scale Graph Visual Analytics
Streaming Analytics	Analytics Using STINGER; Deep Learning on Multilingual Social Media; High-performance Algorithms and Software for Clustering Based on Constrained Low-rank Approximations; Scalable Approximate Graph Clustering on Streaming Data; STINGER Optimizations for High-performance Computing Platforms; StreamSmart
Compute Intensive Analytics	Classification and Phylogenetics of Malware; Event Analysis and Recurrent Pattern Discovery; Message Passing Interface-based Machine Learning; Myria Middleware: Unified Services for Hybrid Big Data Systems; Typograph for Exploring Text Algorithm Outputs
Novel Architectures	Automata Processor; Neuromorphic Computing; System Software for Data-Vortex-based Environments

(High Performance Data Analytics, https://www.pnnl.gov/computing/HPDA/ResearchAreas/, 2022.09.19)

Further examples of applications can be found in (Nagel, Kröner & Resch, 2018), (Nagel, Kröner & Resch, 2016a), (Nagel, Kröner & Resch, 2016b) (Nagel, Kröner & Resch, 2015) and (Voevodin & Sobolev, 2019), and (Yokota, Weiland, Shalf & Alam, 2018), for example. A sample of big data applications are discussed in (Wang, 2017).

The European Community defined a strategic goal to become the leading world HPC player. The European High Performance Computing Joint Undertaking (EuroHPC JU, https://eurohpc-ju.europa.eu/, 2022.09.22), substantiates this effort in many directions: novel hardware with the European Processor Initiative, (EPI, https://www.european-processor-initiative.eu/); central points of contact for HPC and related technologies in each country (EuroCC, https://www.eurocc-access.eu/). High-impact scientific discovery and engineering research and development across all disciplines is the goal of the Partnership for Advanced Computing in Europe (PRACE, https://prace-ri.eu/, 2022.09.22). A current list of European HPC projects is available at (ETP4HPC Handbook of European HPC projects, https://etp4hpc-handbook.online/?_status=on-going, 2022.09.22).

In the education area it is worth mentioning the European Master for High Performance Computing (EUMaster4HPC, https://eumaster4hpc.uni.lu/, 2022.09.22). This project brings together a set of major players in the higher education area to develop a joint curriculum relying on some of the best education specialists in Europe. The EuroHPC JU has procured eight supercomputers, that are deployed across Europe, with the third fastest computer system in the world, as can be seen in Table 3.

On May 2022, the U.S.A. built Frontier supercomputer system became the first true exascale machine with a score of 1.102 Exaflop/s, according to the TOP 500 list (TOP 500, https://www.top500.org). Although Europe still doesn't lead the world in terms of supercomputers, and still doesn't produce its own equipment and processors, it is approaching this goal. The LUMI computer system has 1,110,144 cores, based on a set of AMD Instinct MI250X Accelerators [2].

Table 3: Joint EU HPC supercomputers deployed across several European countries from 2019 to 2022.

designation	country	PFlop/s (sustained)	Pflop/s Rmax (TOP 500)	TOP 500	Internet link
LUMI	Finland	375	151.9	#3	https://www.lumi-supercomputer.eu/
Leonardo	Italy	249.47			https://leonardo-supercomputer.cineca.eu/
MARENOSTRUM 5	Spain	205			https://www.bsc.es/marenostrum
VEGA	Slovenia	6.92	3.82	#131	https://izum.si/en/hpc-en/
MeluXina	Luxembourg	12.81	10.52	#48	https://luxprovide.lu/
Karolina	Czech Republic	6.75	6.75	#79	https://www.it4i.cz/en
Discoverer	Bulgaria	4.51	4.52	#113	https://sofiatech.bg/en/
Deucalion	Portugal	7.22			https://macc.fccn.pt/

(Our supercomputers, https://eurohpc-ju.europa.eu/about/our-supercomputers_en,2022.09.19)

To compare the performance at several scales of HPC computer systems we can look at the information presented in Table 4. It ranges from the Raspberry Pi 4 to low cost entry level supercomputer systems such as the Supermicro Server AS-4124GQ-TNMI and the VEGA supercomputer. Most systems support a common set of message passing and shared memory programming models. This substantiates the assertion that HPC techniques can be used at multiple scales of hardware devices. Applications can be programmed taking advantage of the common properties of these systems across the whole gamut of devices. Another important issue related to HPC is the question of the energy consumption and this is addressed in (Gruber & Keller, 2010).

2 This is allegedly the fastest GPU based accelerator in the market, (https://www.amd.com/en/products/server-accelerators/instinct-mi250x), and many recent supercomputers architectures are based on these GPUs.

Table 4: Performance comparison at several computing scales for HPC.

system	GFlop/s	Available HPC API	# cores	applications
Raspberry Pi 4 CPU (BCM2711B0 A72)	~10.9	OpenMP, MPI	4	Edge computing
Raspberry Pi 4 GPU Video Core IV	~24	OpenCL	64	Edge computing
NVIDIA Jetson Nano GPU GM20B	~235.8	OpenCL, CUDA, OpenAcc	128	Machine learning edge computing
AMD Ryzen 5995WX	339	OpenCL, OpenMP, MPI	64	Top level CPU
GeForce RTX 4090	~82 580	CUDA, OpenCL, OpenACC	16384	Top level graphics card
Supermicro Server AS -4124GQ-TNMI 4x NVIDIA A100	~77 960	CUDA, OpenCL, OpenACC	27648	HPC low cost system for machine learning
VEGA supercomputer 240 000 NVIDIA A100	~959 000 000	MPI, OpenMP	> 3.8 000 000	Scientific computing

The Raspberry Pi 4 is one of the most used edge computing devices used in IoT. HPC technologies are supported on this device. Some of the benchmark results about the performance of the Raspberry Pi 4 show that some applications, with an HPC API, can be fruitfully programmed on this equipment[3]. CPUs are at the heart of embedded systems. Whether one CPU or a combination of several CPUs are used to build a multiprocessor, HPC techniques can be used to improve the execution times (Wolf, 2014).

A final word for the new hardware for factor COM-HPC. IoT spurned the development of the COM-HPC new form factor standard, developed and approved by PCI Industrial Computer Manufacturers Group (PICMG), in 2021[4]. It will ease the deployment of systems with HPC hardware support namely at the data communication level.

3. PROGRAMMING MODELS

The two most prevalent programming models are message passing and shared memory (Czarnul, 2018). These are based on prevalent hardware configurations that are commonly found int HPC computer systems. The problems and techniques of programming of HPC applications are discussed in detail in (Geshi, 2019). Namely the underlying architectures and the prevalent message passing and share memory programming models using MPI and OpenMP. Also, the most common bottlenecks are discussed: communications and memory access.

In the message passing programming model, a program running on a program running on one core-memory pair is usually called a process, and two processes can communicate by calling functions: one process calls a send function and the other calls a receive function (Pacheco, 2011). It is thus very important to have a high performance communications network since it is a major factor in how much speedup can be attained.

It is common to find supercomputers made of many smaller computers and processors. Each different computer is called a *node*, and each has its set of processors/cores, a local memory and its is commonly found to have an associated set of *accelerator devices*, such as GPUs. All nodes communicate through a communications network, for example *InfiniBand*, providing theoretical effective throughput of about 1200Gb/s for 12 links (InfiniBand, https://en.wikipedia.org/wiki/InfiniBand, 2022).

MPI is the most commonly adopted message passing API, it is open source, and the OpenMPI and MPICH implementations are commonly found in supercomputer systems, (https://www.mpi-forum.org/, 2022). It provides a standard defining the syntax and semantics, useful for a large set of C/C++ and Fortran users. Many bindings exist for other programming languages such as the *mpi4py*

3 Consult for further results, (http://www.roylongbottom.org.uk/Raspberry%20Pi%204B%2064%20Bit%20Benchmarks%20and%20Stress%20Tests.htm, 2022).
4 More information is available at the web site (https://www.picmg.org/openstandards/com-hpc/, 2022).

package (https://mpi4py.readthedocs.io/en/stable/mpi4py.html, 2022) for Python, and the *mpi* crate (https://docs.rs/mpi/latest/mpi/, 2022) for Rust. The MPI style of programming is a library based approach to the development of parallel applications.

In the shared memory programming model a single physical address space is provided to all processors, and each processor can run its own program using its local memory and cache (Gebali, 2011). The processors communicate using shared variables. This programming model is simple and general. The OpenMP standard specification is the most commonly used for this programming model[5], and most C/C++ and Fortran compilers provide native support for OpenMP. It is an example of a directive based programming model.

The most common programming languages to be found in HPC systems are C, C++ and Fortran. Modern computer programming languages that are finding their way into HPC are Julia, Rust and Python. MPI and OpenMP are supported in most of these languages by bindings to C libraries.

CUDA by NVIDIA, (Cheng, 2014), and the OpenCL standard are examples of low level accelerator programming models (Czarnul, 2018). Both are primarily destined to C/C++ programming and show the best results. OpenCL supports a heterogeneous programming model where code can be executed in CPUs, GPUs or even other dedicated hardware such as FPGAs and ASICs. It is typical of modern supercomputers to adopt a hybrid model mixing MPI or OpenMP with CUDA or OpenCL.

4. HPC EXAMPLE- NOISE REDUCTION IN IMAGES

Image processing is a scientific area where HPC applications are commonly found. This is due to the large data size of images and the relative ease of parallelization of the algorithms. One of the most important problems in the field is image restoration. A noise contaminated image signal is to be restored without the destruction of the most important features, namely edges. An example of an image restoration method is UINTA, presented by (Awate & Whitaker, 2006). This algorithm belongs to the set of methods with the best results, characterized by a strong removal of noise without destructing the signal. BM3D (Dabov, Foi, Katkovnik & Egiazarian, 2007) and the non local means filter (Buades, Coll & Morel, 2005) are examples of the state of the art of these methods. The main problem with UINTA is related to the long execution times due to the kernel density estimation (KDE)[6] of the local probability density function at each point of the image.

The image is modeled as a stochastic field where the noise reduction process adopts a gradient descent approach to the diminution of the local information entropy. The high-level view of the method is:

i. The input degraded image I has a set of intensities $\{x\}_{t\in T}$, where T is the cartesian index set of the points of the image. It also has a set of neighborhoods $\{y\}_{t\in T}$, and regions $\{z\}_{t\in T} = \{(x,y)\}_{t\in T}$. These values form the initial values of a sequence of images $I^0, I^1, I^2, \ldots$, with corresponding intensities $x^1, x^2, x^2, \ldots$.

ii. For each image region z^m compute

$$\frac{\partial \tilde{x}_i}{\partial \tau} = -\frac{\partial h(\tilde{X}|\tilde{Y}=\tilde{y}_i)}{\partial \tilde{x}_i} \approx \frac{1}{|T|}\frac{\partial \log P(\tilde{x}_i|\tilde{y}_i)}{\partial \tilde{x}_i} = \frac{1}{|T|}\frac{\partial \log P(\tilde{z}_i)}{\partial \tilde{x}_i}$$
$$= -\frac{1}{|T|}\frac{\partial \tilde{z}_i}{\partial \tilde{x}_i}\sum_{t_j\in A_i}\frac{G_n(\tilde{z}_i-\tilde{z}_j,\Psi_n)}{\sum_{t_k\in A_i} G_n(\tilde{z}_i-\tilde{z}_k,\Psi_n)}\Psi_n^{-1}(\tilde{z}_i-\tilde{z}_j),$$

where the following expression:

$$G_n(\tilde{z}_i-\tilde{z}_j,\Psi_n)$$

5 The OpenMP specification can be found at https://www.openmp.org/.
6 An overview of the Kernel Density Estimation procedure can be found at https://en.wikipedia.org/wiki/Kernel_density_estimation.

denotates the Gaussian kernel based on the exponential function which usually takes a large time to compute.

iii. Finally construct image I^{m+1}, using finite forward differences on the gradient descent. intensities

Using a full High Definition (FHD) image (1920 x 1080) it takes for a single threaded Julia implementation on an AMD 5900X CPU about 210 minutes. The same image on a multithread Julia implementation (24 cores) takes about 10 minutes. The execution time of an OpenCL implementation on a NVIDIA RTX 3080 GPU is about 7.8 seconds. A huge improvement in execution times in this particular image processing example. The main reason is the easy parallel programming of most image processing algorithms, such as this one. The large amount of available cores in modern GPUs is one of the reasons modern HPC computing is largely based on this type of hardware.

To illustrate the type of noise reduction processing the results of the UINTA method are shown in Figure 1.

Figure 1. The pictures represent, from left to right, the original image, the noisy image and the processed image with the UINTA method.

5. CONCLUSION

A vigorous effort on the deployment of a HPC European made infrastructure is being made. A first set of supercomputers are being deployed across Europe that will soon be followed by another wave of deplyments. A large set of computationally demanding strategic applications can be run on these computers since many of them belong to the TOP 500 best computers systems. HPC technologies and programming approaches can be seen from the edge computing seen in the IoT level up to the large supercomputers level. Most HPC applications are based on MPI, OpenMP CUDA/OpenCL, or any hybrid approach combining all of these. A mix of library based programming models with directive based approaches are used. The most used programming languages are C/C++ and Fortran with the possibility of usage, in the near future, of Python, Julia and Rust. A noise reduction image processing application is used as an example of how much improvement could be seen using an OpenCL code.

It is expected that during the next years the classical high performance computing systems will be supplemented by quantum based super computing systems. Although the range of applications of quantum computers is still limited it is expected that in the near future this will change.

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IoT LONG RANGE COMMUNICATION TECHNOLOGIES
LoRa and LoRaWAN

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1. INTRODUCTION

Communication technologies are fundamental in Internet of Things (IoT) systems. They generally include short-range and long-range classes and both classes can include wired and wireless technologies. Low-power, long-range wireless networks are increasingly common and play a key role in IoT systems that can operate autonomously over long periods of time and be deployed in large and remote areas, as those that are designed for environmental monitoring.

The paper presents an overview of the main characteristics of low-power wireless communication technologies, with a focus on the needs of environmental monitoring systems developed within the IoT framework. We present the main features of LoRa communication technology and of the LoRaWAN communication protocol, from the perspective of a system integrator, with focus on their suitability for IoT systems dedicated to environmental monitoring. We present examples based on its implementation on the development of a system demonstrator for water quality and water resources monitoring within the AquaQ2 project.

In section 2, the role of communication technologies in IoT is reviewed, with a focus on wireless communication technologies. Section 3 presents the most relevant features of the low-power wide area network technologies and concludes with the importance of LoRa and LoRaWAN in IoT systems dedicated to environmental monitoring. Section 4 describes the LoRaWAN protocol and the LoRaWAN system architecture. An IoT system designed for water monitoring within a research project of the authors is presented in section 5. A summary of the results an experience obtained with this technology is presented in Section 6.

2. IOT COMMUNICATION TECHNOLOGIES

The idea of spreading computers ubiquitously throughout the environment, with a focus on how computers would interact with the rest of the real world was at the basis of the IoT paradigm: a smart environment where the physical world is richly and invisibly interwoven with sensors, actuators, displays, and computational elements, embedded seamlessly into the everyday objects of our lives, and connected through a continuous network (Weisser *et al.*, 1999; Gubbi *et al.*, 2013). With recent improvements in sensors, processing devices, and communication technologies, this paradigm has become a reality, and ranges from small systems that contain a few unique identifiable things to systems that interconnect millions of things with the ability to provide complex services to the end user (Minerva *et al.*, 2015).

Communication technologies are at the backbone of IoT systems. They range from short-range classes, at the sensor and microcontroller level, to long-range classes, at the cloud computing level. All classes can include wired, wireless, or both types of communication. Wired communications are primarily by UART, I2C, or SPI at the microcontroller scale; RS232, RS485, USB, SDI-12, or USB between devices; or ethernet at the cloud scale (Santos *et al.*, 2021).Wireless technologies include NFC, Bluetooth, WiFi, ZigBee, on the small range scale; the several cellular variants – 2G, 3G, 4G and 5G – on the long range scale; SigFox, Narrow-Band IoT (NB-IoT) and LoRa are the three competing Low-Power Wide Area Network (LPWAN) technologies, that provide the low cost, low power and wide-area coverage very convenient for vast and granular wireless sensor networks (WSN) (Olatinwo & Joubert, 2019).

When using wireless communication technologies, there is a trade-off between the range over which the devices can communicate, their maximum data rate and their power consumption. As a general trend, with enough power available, the devices can afford to have higher data throughput and/or move further from the source (Sierra & Odziemczyk, 2020). Wireless technologies can be grouped according to these trade-offs, as shown in Figure 1.

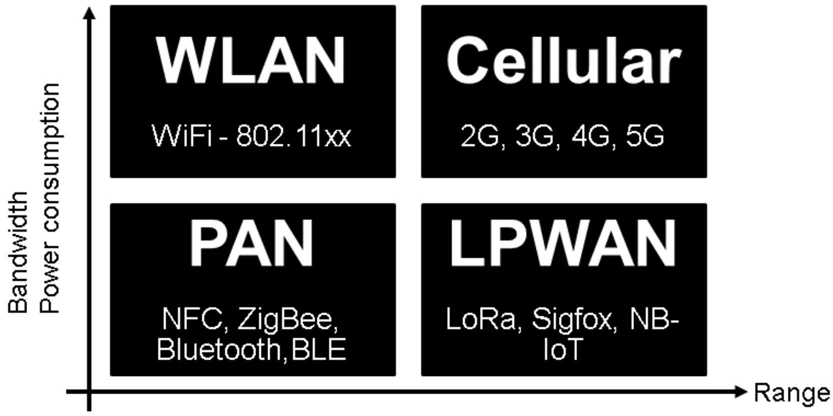

Figure 1. Wireless technologies – grouped in a simplified way according to the power consumption, delivered bandwidth and range. Adapted from (Sierra and Odziemczyk, 2020)

3. LOW-POWER WIDE AREA NETWORK TECHNOLOGIES

LPWAN technologies are ideal for supporting large-scale IoT networks where a significant range - a few kilometers in urban areas to tens of kilometers in rural settings - is required, made up of low-cost devices that need to run on inexpensive batteries for long periods – months or even years. However, LPWANs can only deliver small blocks of data at a low rate. Their simplified and lightweight protocols reduce complexity in hardware design and lower device costs. The long range, combined with typical topologies, reduce costly infrastructure requirements. Also, the use of license-free or already owned licensed bands, reduce network costs.

Many IoT systems are compatible with the bandwidth limitations of LPWAN technologies. In smart cities, smart agriculture, or environmental monitoring, the telemetry applications can usually be made with sensor nodes designed to deliver small data packets at low frequencies. It is estimated that by 2025, 1/4 of the wireless connections used in IoT will use LPWAN (BehrTech, 2022).

Sigfox is an ultra-narrow band network that occupies 100 Hz and operates in unlicensed Industrial, Scientific and Medical (ISM) sub-GHz bands: 868 MHz in Europe, 915 MHz in North America, and 433 MHz in Asia. Because SigFox operates in unlicensed bands, the duty cycle is limited (1% for example for Europe). The maximum data rate is 100 bps. It supports both uplink (UL) and downlink (DL) communications with 140 messages per day for UL communications and 4 messages per day for DL communications. SigFox networks present a star topology with end devices (ED), or nodes, connected to the SiFox cloud through SigFox base stations. The use of an ultra-narrow band in sub-GHz ISM bands enables efficient band use and provides very low noise levels, leading to low power consumption and high receiver sensitivity (Lalle *et al.*,2019).

NB-IoT, also called LTE Cat NB1, is an ultra-narrow band technology developed by the 3GPP group which can used on GSM and LTE networks. It occupies 200 kHz bandwidth, connects up to 100k EDs per cell using existing cellular network operators, and can reach up to 200 kbps data rate for UL and up to 20 kbps for DL communications. The maximum payload of each message is 1600 bytes. NB-IoT provides up to 10 years of battery life, large coverage, low cost, and high network security (Lalle *et al.*,2019).

LoRa, which stands for Long Range, is a physical layer technology that was first introduced in 2009 by Cyclo, a France startup, and was acquired by Semtech in 2012 (Semtech, 2022). It also works in the unlicensed sub-GHz ISM bands - 868 MHz in Europe, 915 MHz in North America, and 433 MHz in Asia - thus having duty cycle restrictions (1% in Europe). LoRa uses an original modulation process, patented by Semtech, based on Chirp Spread Spectrum (CSS). This process provides very high sensitivity (-137dBm), granting long range and good indoor coverage. Different spreading factors (SF7 to SF12) adapt the data rate and range trade-off: the lower SF enables shorter range at the expense of higher data rate, and vice versa. LoRa provides a data rate between 300 bps and 50 kbps, depending on the SF and the bandwidth. The maximum payload is 243 bytes, and the number of messages transmitted per-day, both in UL and DL, is unlimited. The battery life of EDs may span over 10 years (Lalle *et al*.,2019).

LoRaWAN is an open protocol standardized in 2015 by the LoRa Alliance, comprising several hundreds of enterprises, around LoRa technology. It defines the Medium Access Control (MAC) layer for the network. LoRaWAN network architecture is generally deployed in a star-of-stars topology illustrated in Figure 2, in which Gateways (GW) seamlessly relay data between EDs and a Network Server (NS). Security in granted by mutual identification of network components and by end-to-end messages encryption (Lalle *et al*.,2019; LoRaAlliance, 2017; LoRaAlliance, 2020).

A comparison of the three networks is shown in Table 1. When LPWAN characteristics are considered LoRaWAN have become a strong candidate for IoT systems dedicated to environmental monitoring because of its maturity, good radio and capacity properties, security, availability of devices and chips, backend features and its facility of integration with other services.

Table 1. Comparison between the three popular LPWAN technologies (Lalle et al.,2019).

	LoRaWAN	SigFox	NB-IoT
Battery Life	> 10years	> 10years	10years
Range	5km urban, 20km rural	10km urban, 40km rural	1 km urban, 10 km rural
Frequency Band	sub GHz ISM bands	sub GHz ISM bands	Licensed LTE bandwidth
Network Topologies	Star-of-stars	Star	Star
Maturity Level	Some deployments	In use commercially	Early stages
Modulation Technique	Chirp Spread Spectrum	Ultra-NarrowBand	LTE-Based
Network Topologies	Star-of-stars	Star	Star
Devices	No restriction	only SigFox certified	100 k per cell
Security	AES	Not build in	3GPP (128-256bit)
Data rate	300bps to 50kbps	100bps	200kbps
Maximum payload	243bytes	12 bytes (UL), 8 bytes (DL)	1600 bytes
Adaptive Data rate	Yes	No	No
Deployment Model	Operator-based, Private	Operator-based	Operator-based

4. LoRaWAN ARCHITECTURE

The LoRaWAN architecture consists of End Devices (ED), Gateways (GW), Network Server (NS), and Application Server (AS), according to Figure 2. The EDs can offer remote control capabilities having the ability to forward data to one or more GWs via the LoRa physical layer. Each ED, or node, consists of a microcontroller unit (MCU), usually also used to control sensors, that manages a LoRa transceiver, with the LoRaWAN stack, transmiting the data by messages to one or more GW modules. Every GW transmits the received data to the NS, employing every backhaul (wired, Wi-Fi, satellite, or Ethernet). The NS server is the intelligent unit that controls the network, conducts security checks, filters redundant packets, etc. The main compromise of this technology is the limitation of the receiving time slots of the ED. In addition, when a message is sent to the server, the node has allocated only a limited receiving time slot, when it can receive messages from the Application Server side.

LoRaWAN defines a protocol to implement security from the end device to the AS, encrypting the messages exchanged between the two. This protocol uses the AES-128 algorithm to encrypt themessage with two different keys. The first key (NwkSKey) is used to encrypt all the messages between the ED and the NS. The second key (AppSKey) is used to encrypt only the data between the ED and the AS. In the architecture, the NS and the GW have no access to the data encrypted with AppSKey.

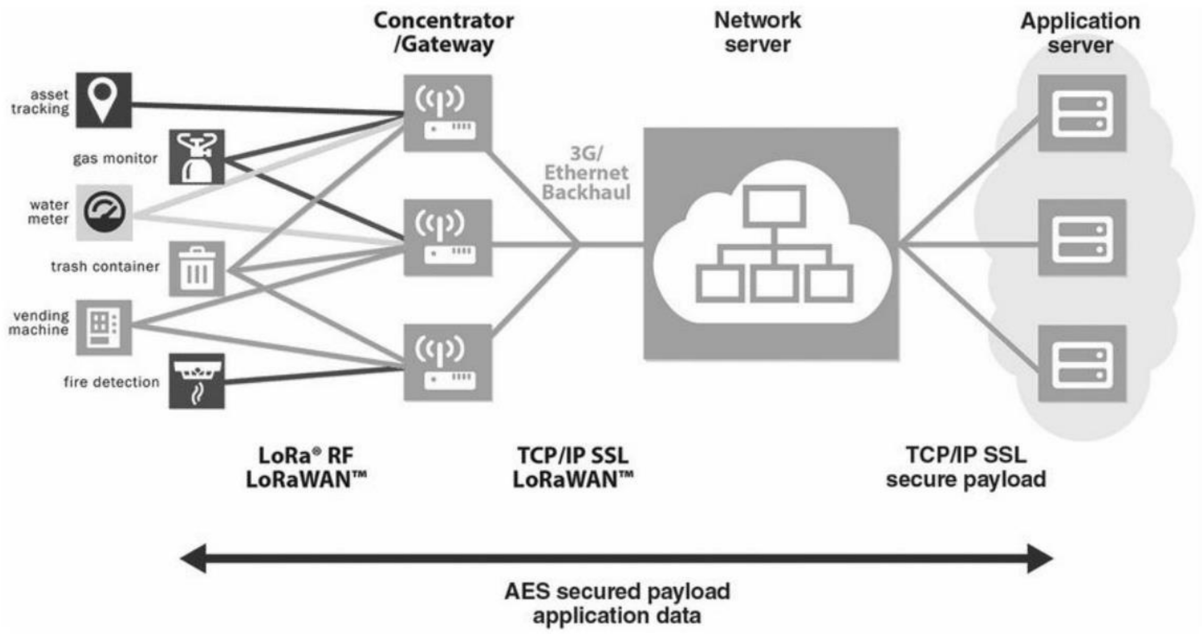

Figure 2. LoRaWAN architecture: end nodes, gateways, network server, and application server (Semtech, 2022).

Three different classes of devices are supported by LoRaWAN: A, B and C. Class A devices are battery powered and constitute the most common ED. When an uplink is sent to the server, the device opens two short downlink windows for eventual commands. If the server cannot send a downlink communication in these two short windows, it will have to wait for the next uplink message, as presented in Figure 3. Class B devices are battery-powered. Also, the two short windows of Class A and Class B have extra downlink windows which are opened at scheduled times. The windows are synchronized with the server using a Beacon from the gateway and respond to the server when the end device is listening. Class C devices are electrically powered. The receive windows are, most of the time, continuously open and close only in the process of transmission.

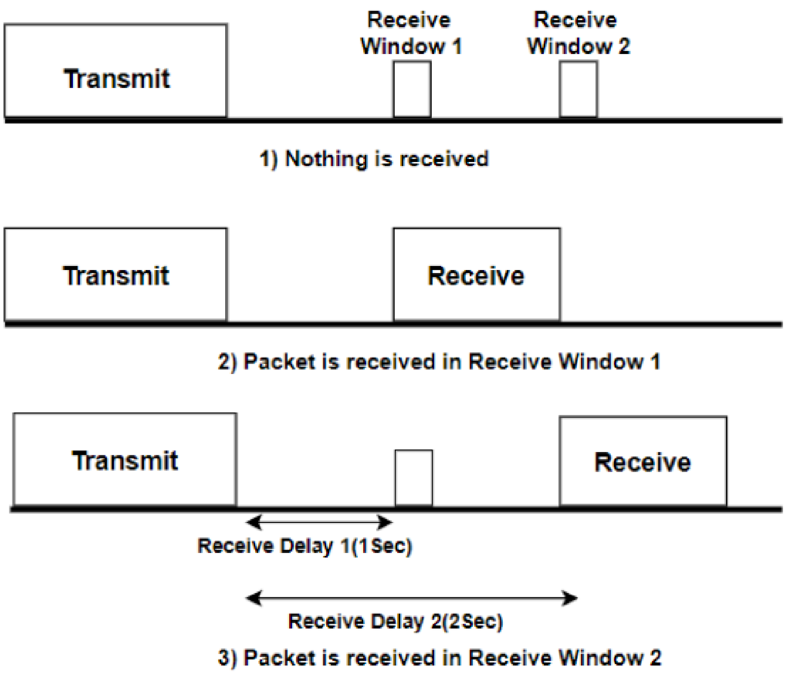

Figure 3. LoRaWAN Class-A Data Transmission (Bhusal, 2020).

5. AN IOT SYSTEM FOR WATER MONITORING

The architecture of a water quality and weather data collection developed within the AquaQ2 project (Carvalho *et al.*, 2022) is represented in Figure 4 and Figure 5. The system may be divided into, roughly, the following types of data processing subsystems: data collection, data transmission and data management, which includes storage and high-level processing. The data collection subsystems are represented in Figure 5. These include the Water Quality Module and the Weather Station Module. Both modules deliver data to the gateway via LoRaWAN technology. The Water Quality Module provides the acquisition of the most common physical and chemical water quality parameters, namely: pH; ORP; DO and EC. The Weather Station is a device which provides meteorological data from the surrounding environment, namely: air temperature, air humidity, air pressure, precipitation, wind velocity and wind direction, luminosity and UV radiation.

The data transmission system adopts the ChirpStack (Brocaar, 2020), an open source LoRaWAN Network Server stack with five major components: a LoRa Gateway Bridge; a LoRa Network server; a LoRa Application Server and a MQTT Broker.The LoRaWAN Gateway receives the information from the data collection modules, that can be placed at distances ranging from some tens of meters to some kilometers. A single LoRaWAN Gateway can accommodate 1,000s of devices or nodes. It transforms the format produced by the Packet Forwarder, and the LoRa gateway forwards the data using an MQTT broker to publish the sensor data and exchange the control data with the LoRaWAN network/application server. The LoRa Gateway Bridge converts the packet forwarded UDP protocol data into JSON and sends/publishes it to the LoRa Network Server, using a subscription on a MQTT server. The LoRa Network Server eliminates duplicate or redundant information and handles the received uplink frames from gateway(s), handles the LoraWAN MAC layer and schedules the downlink data transmissions. The LoRa Application Server handles the join-requests, encryption of application payloads and offers external services.

A sample of the visualization application is presented in Figure 7, where with real-time readings from each sensor in the water quality monitoring module and plots of the readings history.

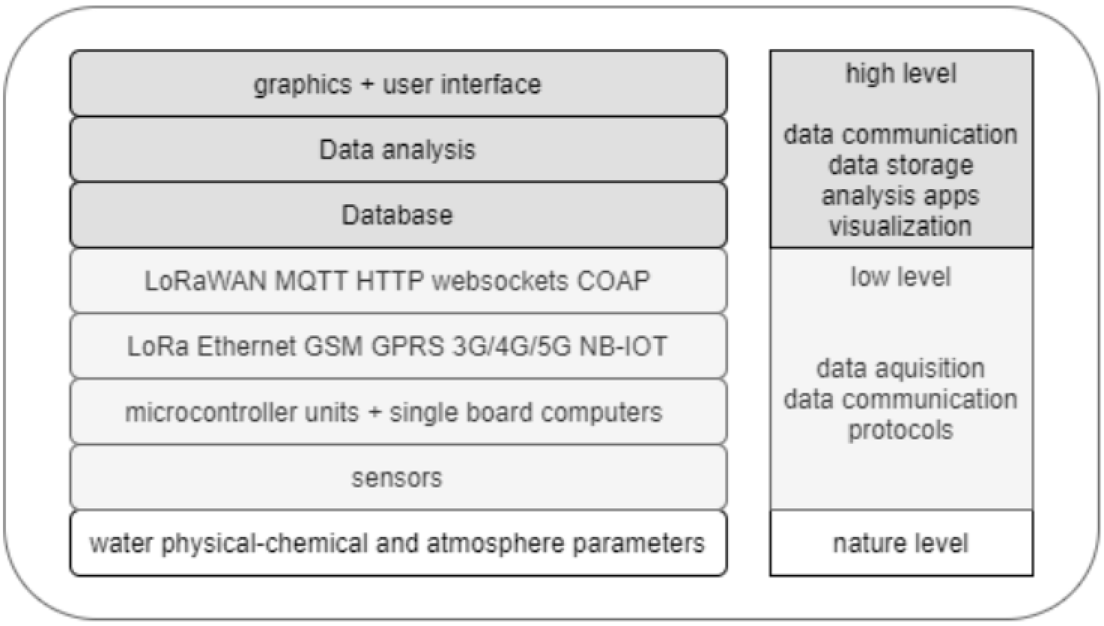

Figure 4. An IoT system for water monitoring: layer diagram (Carvalho *et al.*, 2022).

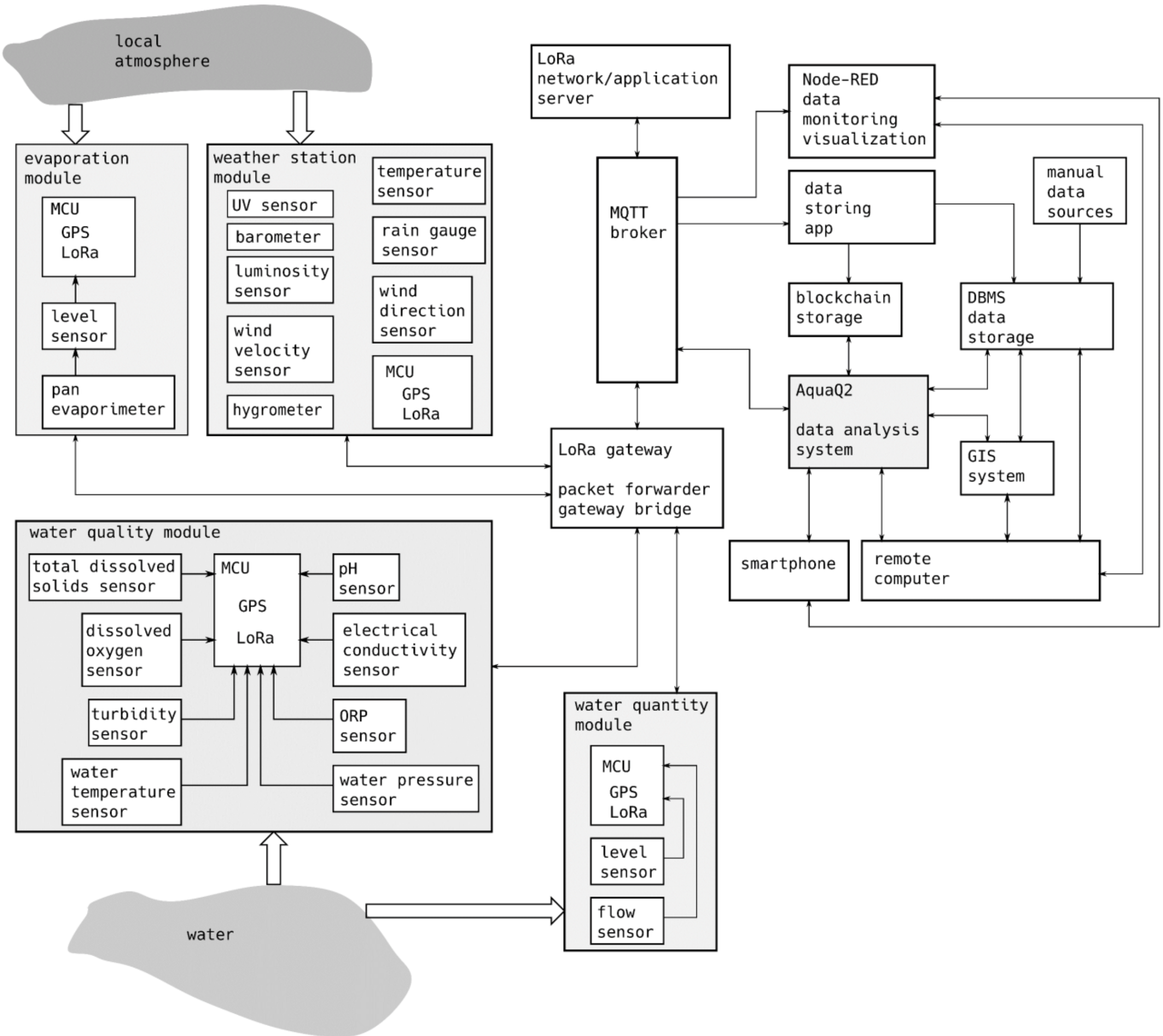

Figure 5. An IoT system for water monitoring: Data Collection and Device Communication Architecture (Carvalho *et al.*, 2022).

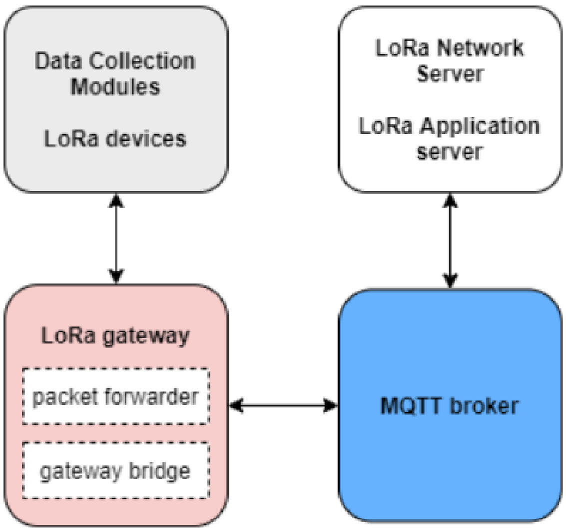

Figure 6. An IoT system for water monitoring: LoRaWAN Communication Architecture (Carvalho *et al.*, 2022).

Figure 7. An IoT system for water monitoring: Data visualization application with real-time readings from each sensor in the water quality monitoring module and plots of the readings history (Carvalho *et al*., 2022).

6. CONCLUSION

Among LPWAN communication technologies to be selected for de development of environmental monitoring IoT systems designed to be deployed over large and remote areas, LoRa and LoRaWAN stand out. Its maturity, good radio and capacity properties that result in long range, and low power consumption, its security, the easy access to devices and chips, its backend features and its facility of integration with other services, make it the first choice for such systems.

The ChirpStack Project, an open source LoRaWAN Network stack with the five major components - a LoRa Gateway Bridge; a LoRa Network server; a LoRa Application Server and a MQTT Broker – proved to be good choice for the implementation of a LoRaWAN based IoT water monitoring system. It's a scalable system that provides full visibility of the data flow and very easy do deploy.

7. ACKNOWLEDGMENT

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IoT MONITORING SYSTEM FOR IRRIGATION CANALS

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1. INTRODUCTION

Water is among the most important resources since it is crucial for every form of life and is becoming scarce, and not always available. To ensure the water quality, measurements must be carried out remotely in dams, rivers, and streams. Water for irrigation is no exception and monitoring its quality is essential to provide farmers with crucial information for its use in an optimal way. Any failure to detect harmful components or parameter values that are outside admissible limits can cause damage to crops and may carry a high risk to public safety and health by contamination. However, irrigation water may include essential nutrients for crops which, when properly quantified, allow for a reduction in the amount of fertilizer to be applied. This grants savings in production costs and less chemicals released into the soils.

This paper describes a prototype system for real time water quality and quantity monitoring in irrigation canals. The parameters indicated by the Portuguese legislation are used as reference, in particular the Portuguese Republic Law 236/1998 of August 1st Annex XVII (DL236, 1998) and the Rectification 22-C/1998 of November 30th (R22-C, 1998), as indicated by Direção Geral de Agricultura e Desenvolvimento Rural (DGRADE, 2019), together with the indicators prescribed by FAO (Food and Agriculture Organization of the United Nations) in the Water Quality for Agriculture field guide (Ayers & Westcot, 1989). The data collection achieved with this system does not replace traditional laboratory water quality analyses, as they must kept being carried out by credited entities, but serves as a form of continuous and preventive control and monitorinig. Furthermore, with the absence of certain sensors and reliable methods to be used *in situ*, it is not possible to measure and analyze some of the important parameters.

The system is intended to automate the acquisition of information on the quality and quantity of water through the implementation of a sensor network infrastructure that obtains, processes, and stores the main parameters values to be analyzed. It is built within the IoT framework, using low-cost sensors for water temperature, pH, flow (instantaneous and accumulated) and total dissolved solids (TDS) measurements. Auxiliary sensors, to collect ambient temperature and humidity, are added to compensate the readings of the pH and flow parameters. The sensors are controlled by ESP32 microcontroller unit (MCU) using the Micropython programming language and data is sent to a central server using LoRa communications.

The system architecture and its conception in terms of hardware and software are presented in section 2, where the components that make up the IoT prototype system are identified, specified, and described. Section 3 presents the implemented system, experimental results, and their evaluation. Section 4 concludes the paper by summarizing the results and suggesting improvements to be made.

2. SYSTEM ARCHITECTURE

The main objective for the prototype was to create a proof of concept for an IoT low-cost, scalable, and non-intrusive system for monitoring the quality and quantity of irrigation water. A widely adopted IoT reference architecture organized on layers was defined by the International Telecommunication Union (ITU), consisting of four layers: devices; network; service support and application support (ITU, 2012). A layer based diagram for the architecture of the monitoring of irrigation canals system prototype, based on (Santos, 2021) and (Carvalho, 2022) is represented in Figure 1.

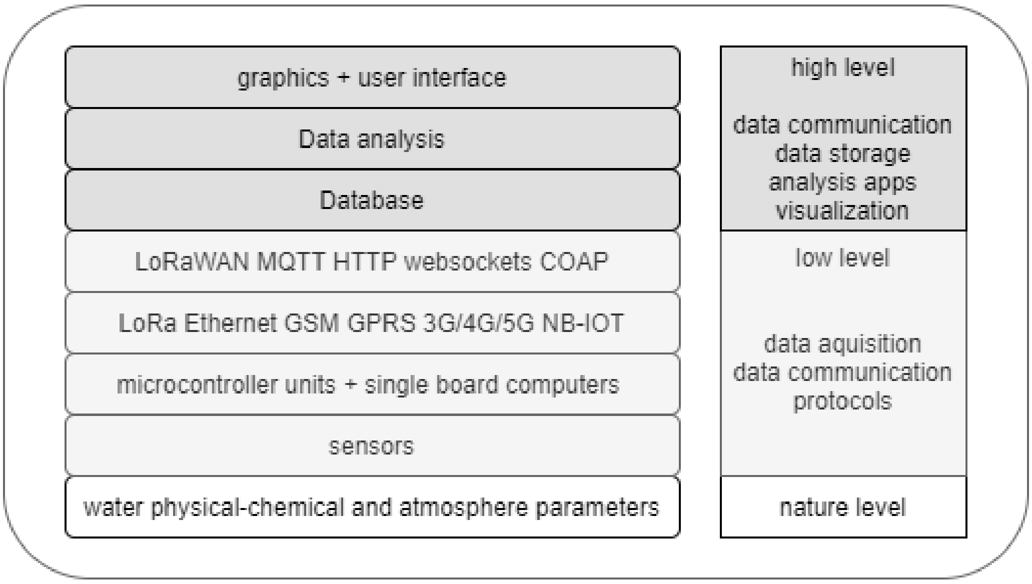

Figure 1. System Architecture: layer-based diagram of an IoT monitoring system for irrigation canals

The sources of data, water and the atmosphere, are at the nature level. The data is collected at low level in the device layer, which comprises sensors and MCUs. Sensors are at the lowest level of the IOT water data collection system. They convert the water and atmosphere parameters to electrical signals. The system includes sensors for measuring water temperature, pH, flow (instantaneous and accumulated), and electrical conductivity. The measurement of the nitrate parameter is not incorporated, as originally planned, due to the high cost of these sensors. At the next level, the sensors are controlled by MCUs that acquire these electrical signals, and convert them to an adequate digital format, ready to be sent through data communication hardware, to the network layer.The network layer comprises the communication technologies and data transmission protocols. It is responsible for receiving the data from the data collection subsystem and transport it to other network devices and servers.The choice of communication technologies is defined by the existing conditions at the data collection site, in particular the geographical conditions, the communications infrastructure and the power sources. Data exchange protocols are responsible for communications with the service support and the application support layer. The service and the application support layer, represents services that enable IoT applications and services.

2.1 Hardware

Low-cost sensors were selected, sometimes sacrificing their accuracy and reliability. The DS18B20 sensor (DS18B20, 2020), manufactured by Maxim Integrated, was the choice for measuring water temperature, and the DHT22 (DHT22, 2020) sensor was selected to measure ambient temperature and relative humidity. For measuring the pH, the PH-4502C sensor with an E-201 probe (PH4502C, 2020) is used. The salinity parameter obtained through electrical conductivity (EC), represents the resistance found by electrical current when passing through water, measuring the amount of dissolved salts or salinity. On the other hand, salinity can also be obtained by the value of total dissolved solids (TDS) (Hussain, 2019). Due to the high cost of the EC sensors, this alternative for measuring the salinity, was opted, measuring the TDS with the Gravity TDS sensor from DFRobot (TDS, 2020).

An important feature of the system is the ability to quantify the water flow at a given point in the distribution network, in the form of instantaneous and accumulated flow. The measurement methods to accomplish this are classified as intrusive and non-intrusive (Quintela, 2007). A non-intrusive method, called the area-velocity method, based on ultrasonic sensors, as shown in Figure 2, was chosen as a proof of concept due to its cost, simplicity and convenience of implementation.

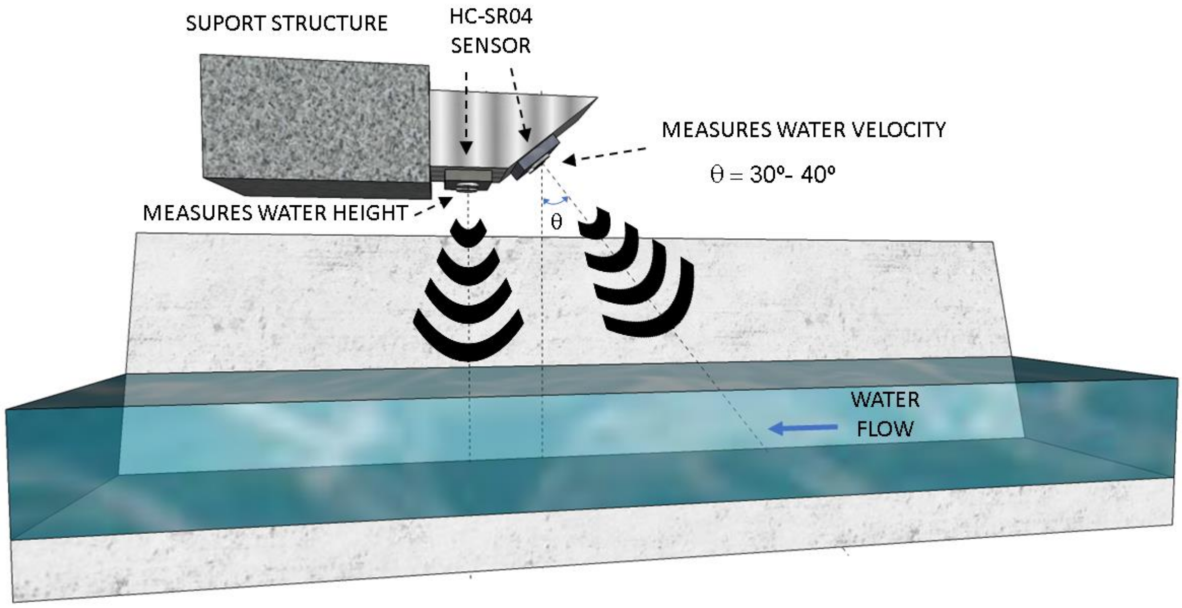

Figure 2. Irrigation canal: ultrasonic flow measurement system.

The measurement system consists of two ultrasonic sensor modules, one to measure the water level and the other to measure the water velocity, by wavelength shifting due to the Doppler effect. A temperature sensor is required to correct the sound velocity. The ultrasonic sensor is mounted at an angle between 30° and 45° degrees relative to the surface of the water, so that the echo of the emitted signal is captured after being displaced by the flow of water. Since the height of the water is variable, the system must be installed in the middle of the cross-section of the channel, which implies to disregard the measurement of the average speed at its theoretical point.

The height of the water level also allows to calculate the flow rate with the Gauckler-Manning-Strickler equation (Quintela, 2007):

$$Q = KAR^{2/3}i^{1/2} \qquad [1]$$

with,

$$Q = Flow[\mathrm{m^3s^{-1}}]$$
$$K = Roughnesscoefficient[\mathrm{m^{1/3}s^{-1}}]$$
$$A = Cross - sectionalarea[\mathrm{m^2}]$$
$$R = HydraulicRatio[\mathrm{m}] = netsection\,area/wet\,perimeter$$
$$i = Canalbedinclination[m]$$

where the cross-sectional area of the water in the channel, A, is a function of the channel geometry and of the height of the water level, a, as shown in Figure 3.

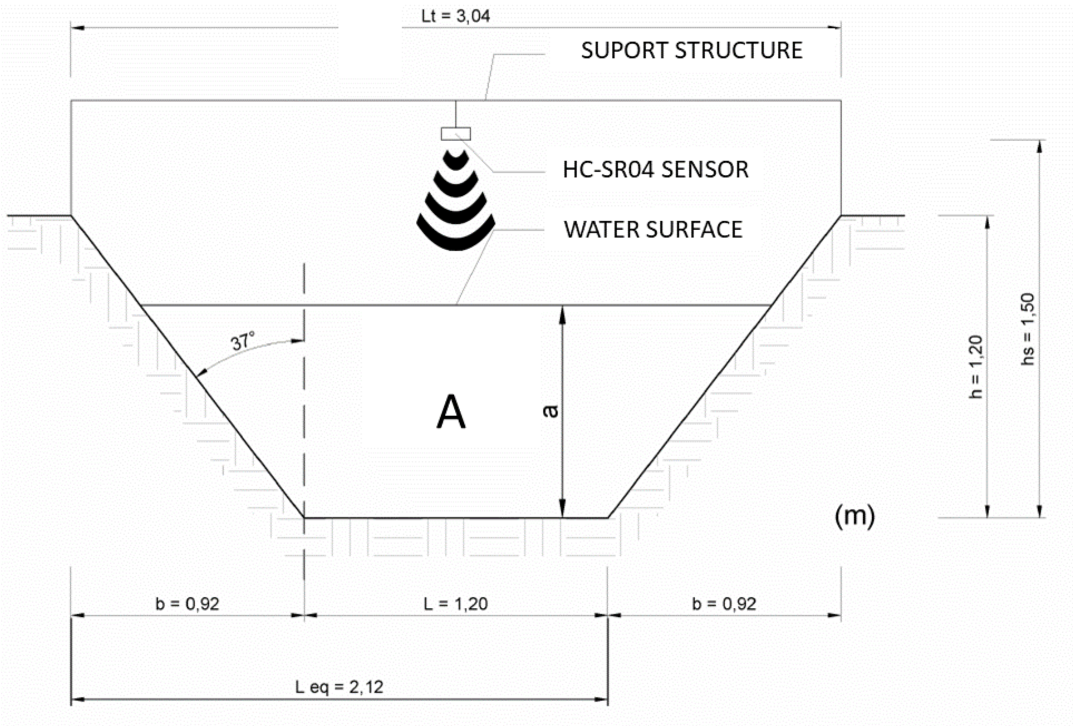

Figure 3. Irrigation canal – transversal cut: typical geometry.

For control the sensors, several computational development platforms were analyzed based on different MCUs. The ESP32 platform, from Espressif Systems (ESP32, 2022), proved to be the most versatile and economically advantageous platform for prototyping or for incorporating into commercial products. Low cost and native integration of communications, such as Wi-Fi, Bluetooth (BT) and Bluetooth Low Energy (BLE), combined with the diversity and quantity of peripherals available, are the main advantages over other platforms. Also relevant is the large flash memory capacity (up to 16MB), allowing the use of the Micropython language. The ESP32D0WDQ6 version (ESP32D0WDQ6, 2022), with 4MB of memory and double processor, was adopted for the emitting nodes. The TTGO T-Call ESP32 SIM800L version (TTGO ESP32 SIM), with GSM/GPRS communication was the choice for the GSM/GPRS gateway node.

Communication between nodes is carried out using LoRa technology (LoRaAlliance, 2020), as presented in Figure 4. The LoRa communication module is based on a SX1276 chip, by Semtech (Semtech, 2020), operating at 20 dB in the 868 MHz band, and featuring a range up to 3000 m, with the aid of the 3.5 dB TX868-XP-100 antenna. Communication of this module with the MCU on the development board is performed by the SPI interface. One of the nodes works as a gateway to publish all collected data.The transmission to publish the data is performed using a GSM/GPRS expansion card with a local UART communication interface to the MCU. The data collected by the sensor's nodes is published online to be visualized and analyzed remotely. This allows a verification of water quality for irrigation in near real time and benefits the farmers when calibrating the nutrients conveyed in the water.

To ensure its autonomy, the system is equipped with batteries charged through photovoltaic panels. Two 3300mAh batteries connected in parallel are recharged via two 5 V, 2.5 W photovoltaic panels, also connected in parallel. To ensure a current and constant voltage load, a charge control module for lithium batteries, model TP4056, is used, granting protection against peaks and polarity inversions.

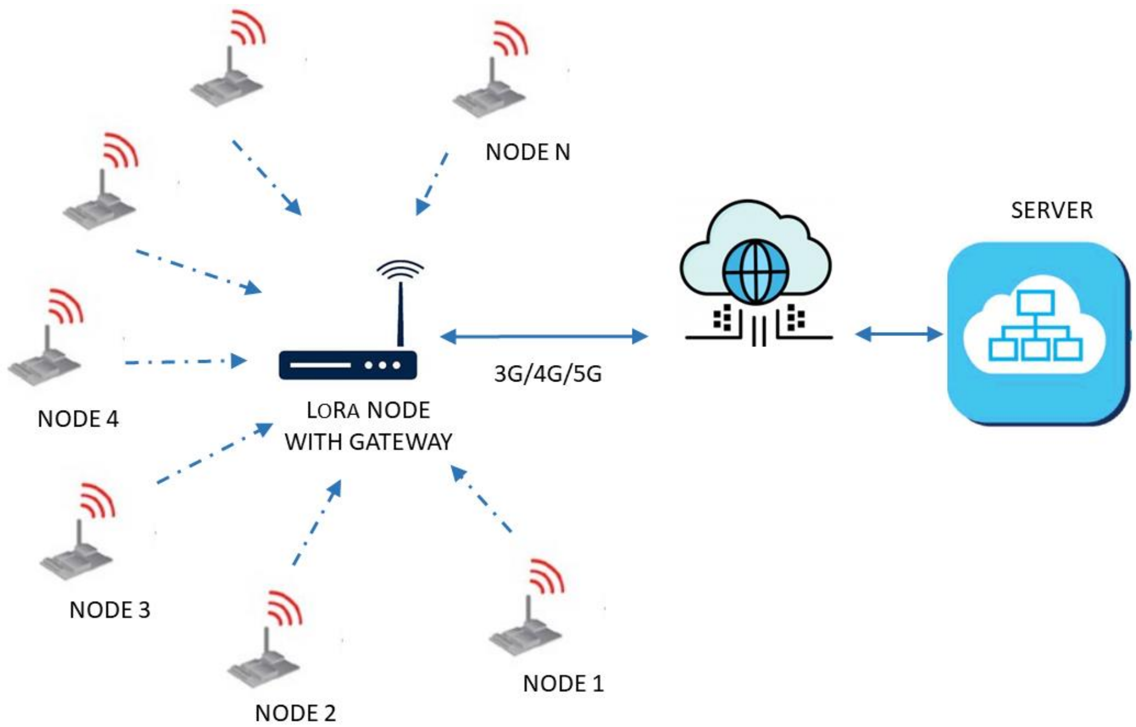

Figure 4. N Nodes network with LoRa communication and GSM/GPRS gateway.

2.2 Software

The prototyping process can be very time consuming by the cycle of writing, compiling, testing, and modification required when using typical microcontroller-oriented programming languages such as C or C+. The Micropython, an interpreted language, like Python, adapted to microcontrollers, was created to overcome these issues and was used in the prototype system to program sensors, communication modules, and development boards. The use of an interpreted programming language does not hinder the integrity of the system as this type of monitoring does not require sampling with high temporal accuracy or frequency. Water quality for irrigation may have extended sampling periods (hours), as most contamination or changes in its properties do not occur nor vary instantaneously. The Thonny IDE was used as the integrated development environment (IDE), because of the ease of sending files to the development board, keeping all the features in one place and their distribution across the three main operating systems (Windows, MacOS and Linux).

3. IMPLEMENTATION AND RESULTS

The two nodes that constitute the prototype, showed in Figure 6, have the same sensors for monitoring the water quality. One consists of a sender node with LoRa and the other a gateway with GSM/GPRS. The gateway node receives all the sender node data and adds it to the publish page created on ThingsSpeak online platform (ThingsSpeak, 2022).

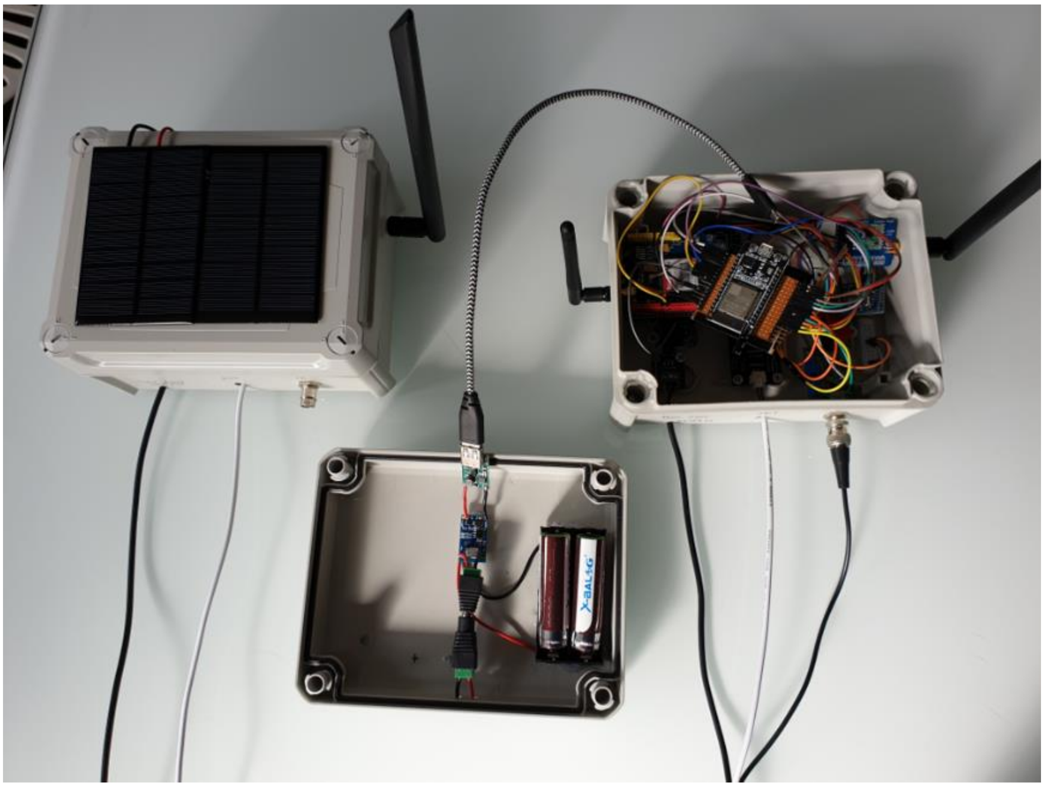

Figure 5. Prototype overview: Top left - Emitter Node; Center and top right - Gateway Node.

The results obtained are presented in Figures 6 to 8. The water temperature measurements are within the limits indicated by the manufacturer. The pH sensor, doesn't show major deviations, but the values denote a deficient calibration, as the water pH should be around 6. The TDS sensor has a very high variation between the maximum value (about 215 ppm) and the minimum value (135 ppm). Since the water was not changed or renewed between readings, it is assumed that this variation results from the poor quality of the sensor. The HC-SR04 ultrasound sensor has not been placed at a specific height so the values it provides for the calculation of the instantaneous flow rate, also denote a lack of calibration. However, they show consistent readings. Consequently, the accumulated flow rate readings, also show less correct values.. The remaining two parameters, ambient temperature and relative humidity, serve only for correction of the ultrasound sensor measurements.

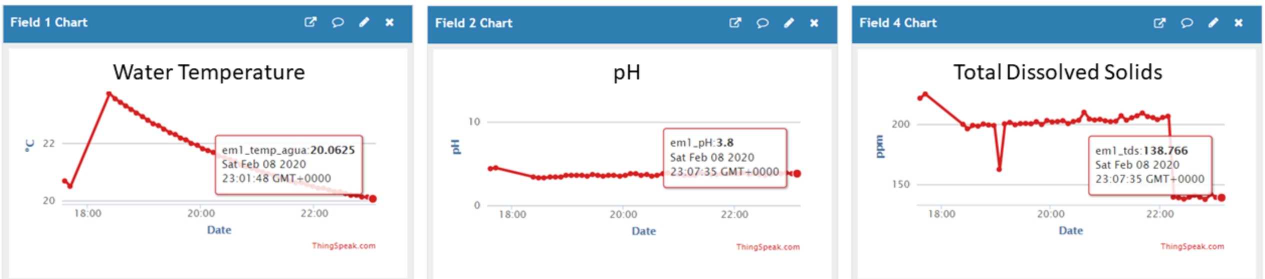

Figure 6. ThingSpeak.com Graphs - Water Temperature, pH and TDS readings.

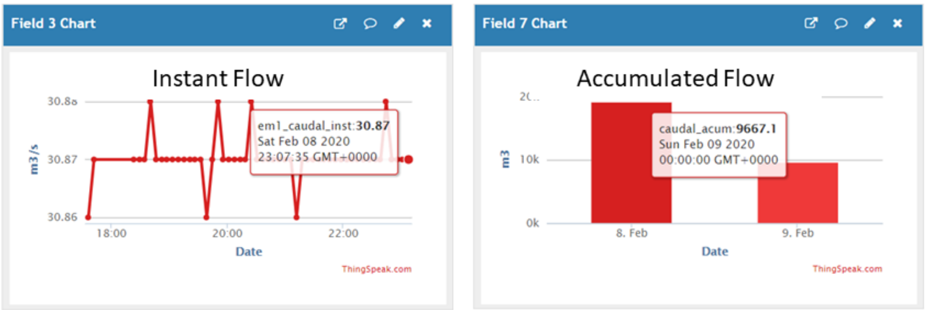

Figure 7. P ThingSpeak.com Graph – Instant and accumulated flow readings.

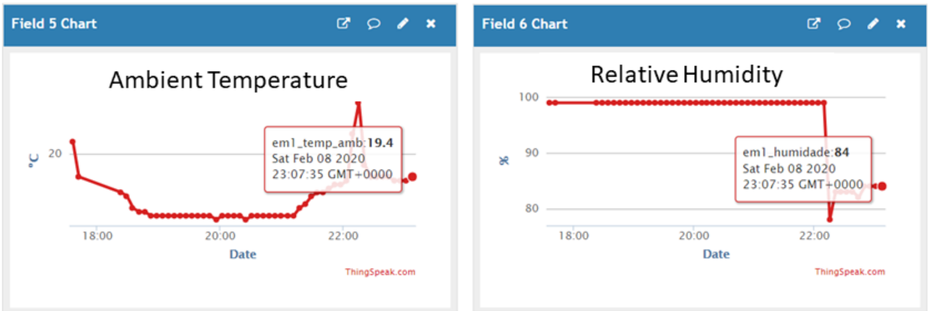

Figure 8. ThingSpeak.com Graph - Ambient temperature and relative humidity readings.

4. CONCLUSIONS

The readings presented by the sensors lack validation using calibrated equipment. Specifically, the values obtained by the pH and TDS sensors are not accurate and the sensors should eventually be replaced by better ones, both in quality and reliability. Although it was not possible to use a nitrate sensor due to cost related reasons, its addition would be relatively straightforward since the prototype allows some degree of scalability. In terms of communication between nodes, LoRa proved to be a good choice. Its low energy consumption allows the use of a low-cost power supply consisting of a photovoltaic panel and 3.7 V batteries. To use the system in a commercial environment, it must be implemented industrial sensors. However, the prototype is functional and constitutes a base platform for developing a water irrigation canal monitoring system.

The use of the Micropython programming language was particularly useful in the sensor testing phase due to the use of REPL (Read-Evaluate-Print Loop). The limitation of Micropython as a programming language for embedded systems was revealed when there is a need to perform more specific tasks, such as using libraries to control specific modules. Poorly detailed or even non-existent documentation, the lack of libraries provided by module manufacturers, and the incompatibility by using different development boards that use Micropython, limits the improvement of the system. Future developments should take into account the traditional microcontroller-oriented programming languages, C and C++.

5. ACKNOWLEDGMENT

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Modular Neural Networks and their Hybrids Selecting Optimal Portfolia

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Abstract**:** The Modular Networks and their Neuro-Genetic Hybrids are examined to address multiple aspects of the modern portfolio theory: i) the investor behavior, ii) the incorporation of the behavior to the stochastic differential equations to describe the price efficiently under the new trends of Chaotic Dynamics described by Tsallis Statistics on entropy in the frame of Fractal Market Hypothesis, iii) the selection of the optimal classifier between 40 Modular models of plain and hybrid form to optimize investment portfolia.

Keywords**:** Genetic Algorithms, Modular Networks, Portfolio Optimization, Entropy, Tsallis Statistics, Chaotic Dynamics, Stochastic Differential Equations

I. INTRODUCTION

The portfolio selection in its second phase elaborates advanced aspects of risk in further higher moments (volatility, hyperkurtosis, ultrakurtosis, hyperultrakurtosis, etc), Loukeris and Eleftheriadis, (2017) and it is analyzed in this paper. At first the portfolios are evaluated to form the feasible set and furthermore the efficient frontier of maximum return under minimal risk on a utility function, Loukeris and Matsatsinis (2006a), Loukeris (2008), Loukeris, Donelly, Khuman and Peng, (2009), Loukeris and Eleftheriadis (2012a), Loukeris Eleftheriadis & Livanis (2014a)], Loukeris, Eleftheriadis and Livanis (2014b), Loukeris and Eleftheriadis (2015b), Loukeris, Bekiros and Eleftheriadis (2016), Loukeris, Bekiros and Eleftheriadis (2016), Loukeris, Chalamandaris, Eleftheriadis (2019),. This paper evaluates the first step which offers the solution to the second step. 40 Modular (MDN) models are evaluated in neural or neuro-genetic hybrids in 11 Modular neural and 33 Modular hybrids, in different topologies that detect the optimal classifier model of portfolio allocation. This research:

I) Examines the preferences and the behavior of investors in advanced moments, on profits and risk exposure,
II) Extends the isoelastic utility as an advantageous tool,
III) Develops Markowitz's portfolio theory, with hidden information of fundamentals, to exclude the bias, and detect healthy assets, in the Fractal Market Hypothesis and Chaos Dynamics in Finance
IV) Examines the efficiency of MDNs in neural or hybrid networks concluding on the optimal classifier for high frequencies trading.

II. Behavior of Investors

The irrational behavior of investors under emotional biases requires a non-linear modeling of higher complexity to describe it. The most turbulent times of the Global Financial Crisis are described by short investment horizons as in the fractal markets hypothesis. Kristoufek (2013), given that returns distributions are not n.i.i.d., and the market failure of EMH. As the investors are more sensitive to their potential losses [13], I model the investment process incorporating the new trends of Tsalis Statistics that describe fractals in the chaotic environment of the stock markets and the Fractal Markets Hypothesis. As the investors allocate their utility expecting a reasonable return, as the fear of loss, produces problematic decisions, they usually are risk averse or risk neutral. Higher moments describe the investors hidden patterns on the implied utility function of the HARA (Hyperbolic Absolute Risk Aversion), thus advanced moments further than the 5th of hyperskewness are used Loukeris and Eleftheriadis, (2017), Loukeris and Eleftheriadis (2015b), Loukeris, Bekiros and Eleftheriadis (2016), Loukeris, Bekiros and Eleftheriadis (2016):

$$U_t(R_{t+1}) = \sum_{\lambda_v=1}^{\omega} (-1)^{\lambda_v+1} \frac{a_{\lambda_v}}{n} \sum_{i=1}^{n} \left(x_i - \sum \frac{x_i}{n} \right)^n \quad [1]$$

where λ_v is the accuracy on investors preferences to risk, depending on the behavior, $a_{\lambda v}$ a constant on investors profile:
$a_{\lambda v} = 1$ for rational risk averse individuals, $a_{\lambda v} \neq 1$ for the non-rational, xi the value of return i in time t. The Isoelastic Utility, a unique HARA function of Constant Relative Risk Aversion, is for the risk averse investors:

$$U = \begin{cases} \dfrac{W^{1-\lambda} - 1}{1-\lambda}, & \lambda \in (0,1) \cup (1,+\infty] \\ \log(x), & \lambda = 1 \end{cases} \quad [2]$$

where, W the wealth, λ a measure of risk aversion. Loukeris, Eleftheriadis & Livanis (2014a, b) indicated the Makowitz model can have a broader alternative relaxing its essential assumption on the normally distributed prices. The initial convex problem of quadratic utility maximization, Markowitz (1952), is non- effective in the markets:

$$\min_x f(x) = Var(r_p) \quad [3]$$

As Maringer and Parpas (2009), incorporated higher order moments:

$$\min_x f(x) = \lambda Var(r_p) - (1-\lambda) E(r_p) \quad [4]$$

$$r_p = \sum_i x_i r_i \quad [5]$$

$$x_i \geq 0 \quad [6]$$

$$\sum_i x_i = 1 \quad [7]$$

where r_p the portfolio return, x_i the weight of asset i, r_i the return of i^{th} asset, μ the mean and σ^2 the variance. Regarding the chaotic dynamics, [16] relative entropy (TRE), which is the generalization of Kullback-Leibler relative entropy (KLRE) to non-extensive systems, describes complex systems with nonlinearity, long range interaction and long-term memory effect. The stock markets research on the Tsallis generalization of the KLRE was implemented by Tsallis, Anteneodo, Borland, Osorio (2003), Kaizoji (2006), Rak, Drozdz & Kwapien (2007), Kozaki & Sato (2008), Queirós, Moyano, Souza, Tsallis (2007), Biró & Rosenfeld (2012), Zhao, Pan, Yue & Zhang (2021).

III. THE MODEL

Loukeris, Eleftheriadis & Livanis (2014a, b), showed that further higher moments are necessary to describe the behavior of investors:

$$\min_x f(x) = \lambda \upsilon_\gamma \left[bVar_t(r_p) + d\,Kurt_t(r_p) + f\,HypKurt_t(r_p) - hUltraKurt_t(r_p) \right])] - (1-\lambda)\upsilon_\gamma \left[aE_t\left(r_p\right) + cSkew_t\left(r_p\right) + eHypSkew_t(r_p) + \mathrm{g}UltraSkew_t(r_p) \right] \quad [8]$$

$$\upsilon_\gamma = 1 - \varepsilon_\tau \quad [9]$$

$$r_p = \sum_i x_i r_i^* \quad [10]$$

where $\upsilon_\gamma$company's financial health (binary: 0 to bankruptcy, 1 healthy), ε_τ the heuristic output as the evaluation result (binary: 0 healthy, 1distressed), r_i^* the return of stock *i* from the efficient frontier and is superior than the others, x_i their weights. Hence

$$U_t(r_p) = \sum_i U_t(R_t(i_i^*) \quad [11]$$

The non-convex problem demands robust heuristics, where I contribute in a more efficient hybrid classifier that considers also hidden accounting among the ordinal data. Thus fraud and manipulation are filtered.

IV. THE COMPUTATIONAL INTELLIGENCE

The classifier that consist the core of this paper will be tested in the various forms of the Modular neural and hybrid and hybrid neuro-genetic networks, on various topologies.

V. THE MODULAR NETWORKS AND THEIR HYBRIDS

Modular feedforward networks are a special class of MLP. These networks process their input using several parallel MLPs, and then recombine the results. This tends to create some structure within the topology, which will foster specialization of function in each sub-module. In the models the number of hidden layers, and the network topology can be defined. There are four modular topologies supported, and in all the models is applied the linear feedforward form without bypasses of the signals.

In contrast to the MLP, modular networks do not have full interconnectivity between their layers. Therefore, a smaller number of weights are required for the same size network (same number of neurons).

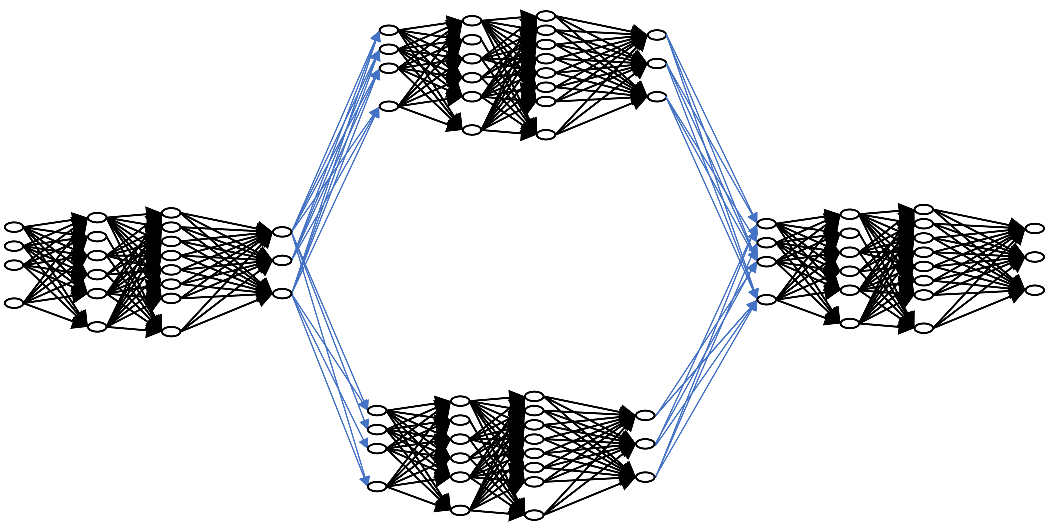

Fig. 1. The Modular Neural Networks

This tends to speed up training times and reduce the number of required training exemplars. There are many ways to segment a MLP into modules. It is unclear how to best design the modular topology based on the data. There are no guarantees that each module is specializing its training on a unique portion of the data. The Input neurons were 16, Output 1, Exemplars 706, in the Hidden layers the Upper Neurons were 4 with no GA, Upper Transfer TanhAxon, Lower Neurons were 4 in no GA, Lower Transfer TanhAxon, Learning Rule was Momentum, Step size 0.1, Momentums 0.70

Backpropagation is by far the most common form of learning, the weights are changed according to their previous value and a correction term. The learning rule specifies the correction term, and the Supervised Learning Control was used, Max epochs: 1000, Termination MSE , threshold 0.01, Minimum criterion, Load best on test, in Batch learning

The Maximum Epochs specifies how many iterations (over the training set) will be done if no other criterion appears. The Error Change box contains the parameters used to terminate the training based on mean squared error.

The Minimum function terminates when the MSE drops below the specified Threshold. The Incremental function terminates when the change in MSE from one iteration to the next is less than the threshold. The default Incremental error is much smaller than the Minimum error.

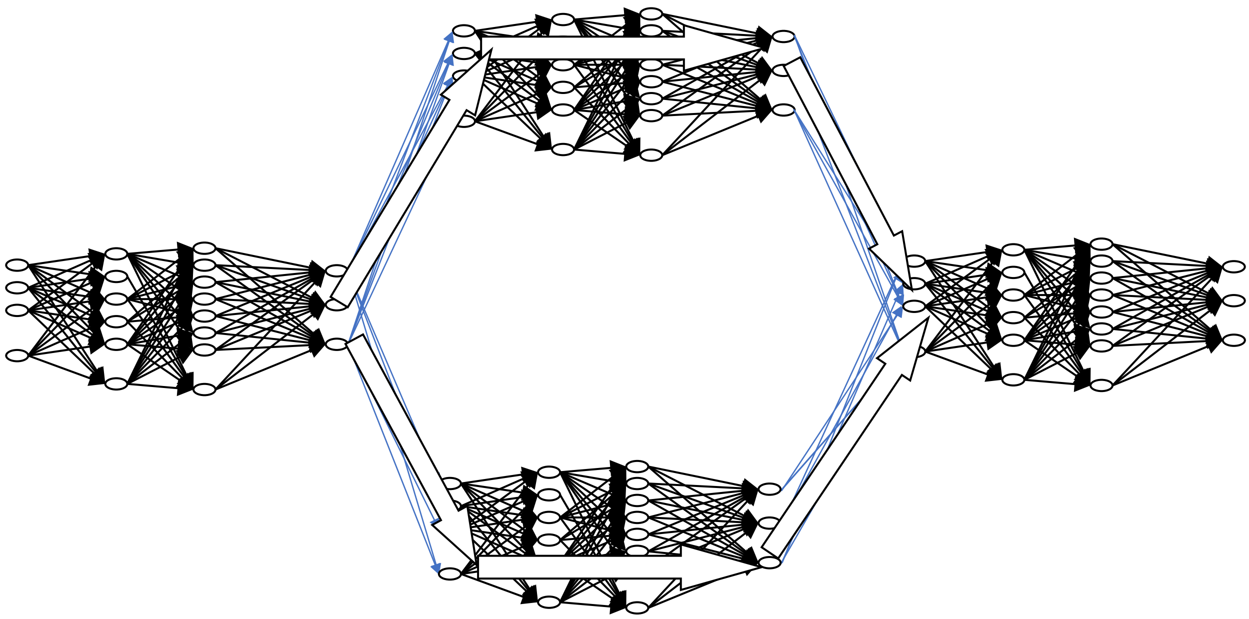

Fig. 2. The signal processing in the Modular models examined was the linear feedforward form without bypasses

The MSE termination bases the stop criteria on the Cross Validation set, instead of the training set. In case the MSE of the crossvalidation set begins to increase, this indicates that the network starts to overtrain, - to simply memorizes the training set and is unable to generalize the problem.

Cross validation is highly efficient method to end network training and it is used in 11 similar hybrid models. It monitors the error on an independent set of data and stops training when this error is starting to increase, offering the best point of generalization to the calculations. The testing set is used to test the performance of the network. Once the network is trained the weights are then frozen, the testing set is fed into the network and the network output is compared with the desired output.

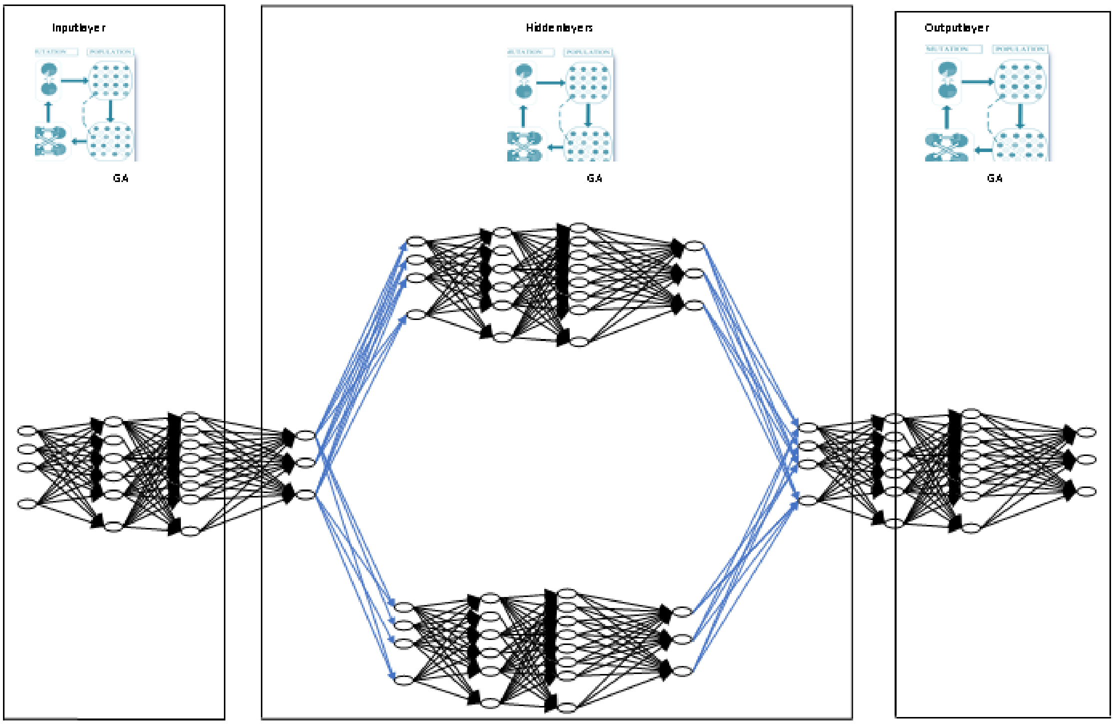

Fig. 3. The Hybrid Modular Net of GA optimization and Cross Validation in all the layers,

VI. PROBLEM DEFINITION

The significance of further higher moments in the model was revealed by Maringer and Parpas (2009), Loukeris, Eleftheriadis & Livanis (2014a, b), Loukeris and Eleftheriadis (2017), that provide a more realistic representation of preferences and thus the dynamic behavior of investors. Loukeris and Eleftheriadis (2017) introduced the form of the problem as:

$$U_t(R_t(i)) = \sum_{\lambda_v=1}^{\omega}(-1)^{\lambda_v+1}\frac{a_{\lambda_v}}{n}\sum_{i=1}^{n}\left(x_i-\sum\frac{x_i}{n}\right)^n + W_x(u,s) \qquad [12]$$

As

$$z = y^2 = \sigma^4 \qquad [13]$$

then identical, [1], to

$$min_x f(x) = \lambda \upsilon_\gamma \sigma^2(r_p)[b + dz + ez^2] \qquad [14]$$

The non-convex form of the problem demands robust heuristics
for the solution. Rumors, manipulation, cooked accounting has higher levels of investment risk. In terms of the Chaotic Dynamics a riskless bond has a price:

$$dB(t) = rB(t)dt \qquad [15]$$

$$B(0) = 1 \qquad [16]$$

where r a risk-free interest rate. Risky stock prices follow the Stochastic Differential Equation, Zhao, Pan, Yue & Zhang (2021):

$$dS(t) = S(t)(\mu dt + \sigma\, d(t) + JdN(t) - \lambda udt) \qquad [17]$$

where μ expected return of the stock, σ volatility without jumps, J a random variable of the jump amplitude within the stock (J > −1). As $u = E\,(J)$ where $E\,(\cdot)$ an expectation operator, $\{N(t)\,, t\geq 0\}$ a Poisson process with strength λ, λudt an average growth by the Poisson jump, $\{W(t),\ t\geq 0\}$ a standard Brownian motion defined on probability (F, {Ft} $t\geq 0$, P), $\{N(t)\ , t \geq 0\}$ and $\{W\,(t)\ , t \geq 0\ \}$ are independent of each other, Zhao, Pan, Yue & Zhang (2021).

The SDE [17] solution is Zhao, Pan, Yue & Zhang (2021):

$$S(t) = S(0)\prod_{i=0}^{N(t)}(1+J_i)e^{\mu t - \frac{\sigma^2}{2}\int_0^t P^{1-q}(\Omega,s)ds - \lambda ut + \sigma\Omega(t)} \qquad [18]$$

The random variable Ω(t) satisfies:

$$d\Omega(t) = Pq(\Omega,t)^{(1-q)/2}dW(t) \qquad [19]$$

where $Pq(\Omega,t)$ the maximum Tsallis entropy distribution of Non-extensive statistics. The model can describe the volatility clustering and long-term memory phenomena of asset prices Zhao, Pan, Yue & Zhang (2021). Given that the return x_i is:

$$x_t = (S_t - S_0)/S_0 \qquad [20]$$

Then [12] is the optimal utility function on this model. This approach was utilized in finance Wang, & Shang (2018), *Loukeris (2021)*.

VII. DATA

Data were produced by 1411 companies from the loan department of a Greek commercial bank, with the following 16 financial indices, Courtis (1978):

1) EBIT/Total Assets**,**
2) Net Income/Net Worth,
3) Sales/Total Assets,
4) Gross Profit/Total Assets,
5) Net Income/Working Capital,
6)Net Worth/Total Liabilities,
7)Total Liabilities/Total assets,
8)Long Term Liabilities/(Long Term Liabilities+Net Worth),
9)Quick Assets/Current Liabilities,
10)(Quick Assets-Inventories)/Current Liabilities,
11)Floating Assets/Current Liabilities,
12)Current Liabilities/Net Worth,
13) Cash Flow/Total Assets,
14)Total Liabilities/Working Capital,
15)Working Capital/Total Assets,
16) Inventories/Quick Assets,

and a 17th index with initial classification, done by bank executives. The test set was 50% of the overall data, and the training set 50%. Multiple combinations were chosen to detect the optimal performance of MDN Networks:
i) MDN neural nets, ii) Hybrid MDNs with GA only on the inputs layer, iii) Hybrid MDNs with GA in All layers, iv) Hybrid MDNs with GA in All layersand Cross Validation

VIII. Results

Regarding the in-sample the best performance was observed by the MDN hybrid with GA in all layers and 2 hidden layer that had a very good classification, an excellent fitness to the model at 0.815, low errors, and low AIC in -741.82 in a medium time of 4h 11' 37''. Although the hybrid MDB of 0 layers and GA in the inputs only, and the hybrid MDN on GA in all layers of 3 hidden layers were ranked 2nd and 3rd respectively their very good performance is biased by the high positive partiality values of the Akaike criterion and thus their contribution should be not robust. On the contrary the hybrid MDN of 1 hidden layer GA in all layers and Cross Validation had a good classification, high performance and low partiality in a medium time revealing a superior efficiency than the 2nd and the 3rdmodles, and is more preferred.

On the Out-of-sample, the Modular Neural Network of 3 layers had the optimal performance of classification within the healthy and distressed assets at 99.16% and 83.48% respectively, high fitness of the model to the data 0.884, the lowest MSE at 0.092, NMSE 0.218 and 4.611%, the AIC was very low at -1230.98 revealing impartiality in a very fast time of 26s.

The second rank was given to the MDN Neural Net of 4 layers, in a highly converged classification, high fitness to the data r 0.880, low error, and impartiality into 28s.

The third rank was given to the Hybrid MDN net of 2 layers, in slightly lower classification, fitness, and error performance, as the impartiality was slightly higher, in 31 hours 47 min. 21 seconds (Table II).

Overall the MDNs had superior performance than the hybrid MDNs models in the out-of sample whilst in the in sample the hybrids were better, as in Tables I, II, and III.

IX. Concluding Remarks

The hybrid MDN of 2 layers and GA in all and the hybrid MDN of 1 layer with GA and Cross Validation in all layers outperformed on the in-sample set, whilst the MDN neural networks of 3 and 4 hidden layers respectively, had superior classification out-of-sample and performance in a very fast processing time, although the Hybrid MDN with Cross Validation of 2 hidden layers, ranked 4th had a better diversity of intertemporal solutions in a medium time of process. Thus the MDN hybrids consist a competitive classifier in portfolio selection.

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TABLE I. MODULAR NEURAL & HYBRID NETWORKS IN-SAMPLE

Models		**Active Confusion Matrix**				**Performance**						**Time**
	Layers	**0→0**	**0→1**	**1→0**	**1→1**	**MSE**	**NMSE**	**r**	**%error**	**AIC**	**MDL**	
MDN NN	0	100	0	100	0	0.565	1.337	0.114	12.846	-368.070	-346.31	4"
	1	99.16	0.83	55.96	44.03	0.202	0.478	0.733	13.196	-837.54	-651.97	19"
	2	99.16	0.83	46.78	53.21	0.194	0.459	0.742	12.358	-866.39	-680.82	6"
	3	100	0	100	0	0.383	0.906	0.511	19.174	-227.11	60.84	7"
	4	100	0	100	0	0.449	1.062	0.077	25.550	-34.87	304.27	8''
	5	0	100	0	100	1.397	3.303	0.102	61.722	846.23	1236.58	10"
	6	100	0	100	0	0.440	1.040	0.095	25.20	110.70	552.23	11"
	7	100	0	100	0	0.423	1.000	-0.055	20.153	162.97	655.69	12"
	8	0	100	0	100	1.219	2.882	0.064	57.67	989.85	1533.77	13"
	9	100	0	100	0	0.432	1.023	0.065	23.82	388.36	933.97	13"
	10	0	100	0	100	1.111	2.628	0.091	55.016	1084.90	1731.20	15"
HYBRIDS												
MDN GA Input	*0*	*98.65*	*1.34*	*31.18*	*68.80*	*0.147*	*0.348*	*0.810*	*8.454*	*1557.50*	*3419.16*	*9.5''*
	1	98.82	1.17	39.44	60.55	0.189	0.449	0.754	12.367	-1026.67	-933.24	46' 39''
	2	99.32	0.67	65.13	34.86	0.222	0.524	0.718	14.521	-756.42	-560.61	2h 47' 02''
	3	100	0	100	0	0.423	1.000	-0.017	19.711	-269.16	-52.88	1h 19' 14''
	4	0	100	0	100	1.084	2.564	-0.048	54.306	507.34	795.29	1h 39' 37"
	5	100	0	100	0	0.467	1.104	-0.038	28.546	-39.19	279.47	1h 58' 49''
	6	100	0	100	0	0.503	1.189	0.232	31.699	61.368	410.75	2h 20' 39''
	7	100	0	100	0	0.467	1.106	-0.249	28.628	89.898	490.47	2h 18' 22''
	8	100	0	100	0	0.456	1.079	-0.083	27.397	168.39	630.40	8h 26' 37''
	9	0	100	0	100	1.294	3.061	0.040	59.444	968.45	1471.41	9h 11' 42''
	10	100	0	100	0	0.435	1.029	0.057	24.321	310.83	885.46	15h 39' 46''
MDN GA All Layers	0	100	0	100	0	0.565	1.337	0.080	12.846	-370.06	-349.59	56' 32''
	1	97.98	2.01	29.35	70.64	0.157	0.371	0.792	9.681	-578.03	-112.18	15h 25' 57''
	2	*97.31*	*2.68*	*22.01*	*77.98*	*0.142*	*0.336*	*0.815*	*7.738*	*-741.82*	*-336.12*	*4h 11' 37''*
	3	*98.49*	*1.50*	*31.19*	*68.80*	*0.153*	*0.363*	*0.802*	*7.816*	*1400.25*	*3142.07*	*12h 14' 15''*
	4	99.83	0.16	92.66	7.33	0.393	0.929	0.267	18.683	2923.02	5215.16	17h 48' 44''
	5	100	0	98.16	1.83	0.416	0.984	0.124	19.281	3535.48	6193.64	22h 55' 13''
	6	100	0	100	0	0.498	1.177	-.0314	7.964	4490.11	7678.11	27h 11' 11''
	7	100	0	99.08	0.91	0.420	0.993	0.090	19.470	7303.63	12369.11	40h 10' 29''
	8	100	0	100	0	0.565	1.336	-0.005	12.824	4253.52	7232.92	34h 09' 30''
	9	100	0	100	0	0.422	0.999	0.043	19.579	10362.52	17382.26	58h 11' 13''
	10	100	0	100	0	0.418	0.990	0.126	19.489	5711.46	9759.50	45h 27' 04''
MDN GA ALL CV	0	98.32	1.67	33.02	66.97	0.164	0.389	0.781	10.120	-1248.47	-1233.12	21' 51''
		98.82	1.17	36.69	63.30	0.155	0.367	0.799	9.459	-1287.16	-1271.81	
	1	98.82	1.17	39.44	60.55	0.165	0.392	0.786	11.249	-465.89	47.30	5h 34' 57''
		99.16	0.83	45.87	54.12	0.171	0.406	0.788	7.878	-439.20	73.71	
	2	100	0	100	0	0.555	1.313	0.124	12.703	597.03	1244.61	9h 14' 06''
		100	0	99.08	0.91	0.560	1.323	0.095	12.777	603.89	1251.11	
	3	98.15	1.84	33.02	66.97	0.170	0.403	0.775	10.662	295.75	1283.76	14h 2' 54''
		98.99	1.00	39.09	60.90	0.170	0.395	0.785	9.947	296.86	1284.87	
	4	100	0	100	0	0.376	0.890	0.702	19.968	2698.71	4866.70	26h 40' 56''
		100	0	100	0	0.379	0.895	0.701	19.943	2704.05	4870.84	
	5	100	0	100	0	0.422	0.999	0.223	19.584	3426.41	6007.78	30h 21' 00''
		100	0	100	0	0.423	0.999	0.147	19.590	3428.13	6008.07	
	6	100	0	100	0	0.318	0.753	0.629	19.737	4330.94	7618.77	34h 44' 08''
		100	0	100	0	0.312	0.738	0.729	17.351	4318.36	7604.37	
	7	100	0	100	0	0.423	1.000	0.227	18.737	7449.21	12604.28	54h 43' 44''
		100	0	100	0	0.423	1.000	0.246	19.142	7450.43	12602.64	
	8	99.83	0.16	81.65	18.34	0.326	0.771	0.620	22.660	3529.66	6294.04	8h 32' 31''
		100	0	100	0	0.477	1.128	-0.120	10.652	3799.33	6562.18	
	9	100	0	100	0	0.558	1.320	0.262	12.395	6402.61	10762.91	8h 41' 32''
		100	0	100	0	0.560	1.323	0.257	12.476	6405.91	10763.79	
	10	100	0	98.16	1.83	0.416	0.989	0.155	19.529	9759.77	16400.69	91h 22' 1''
		100	0	99.08	0.91	0.419	0.990	0.127	19.562	9765.75	16402.99	

TABLE II. OPTIMAL MODULAR NEURAL & HYBRID NETWORKS IN-SAMPLE

Models		Active Confusion Matrix				Performance						Time
	Layers	0→0	0→1	1→0	1→1	MSE	NMSE	r	%error	AIC	MDL	
MDN GA All	2	97.31	2.68	22.01	77.98	0.142	0.336	0.815	7.738	-741.82	-336.12	4h 11’ 37’’
MDN GA INPUT	0	98.65	1.34	31.18	68.80	0.147	0.348	0.810	8.454	1557.50	3419.16	9.5’’
MDN GA All	3	98.49	1.50	31.19	68.80	0.153	0.363	0.802	7.816	1400.25	3142.07	12h 14’ 15’’
MDN GA ALL CV	1	98.82	1.17	39.44	60.55	0.165	0.392	0.786	11.249	-465.89	47.30	5h 34’ 57’’
		99.16	0.83	45.87	54.12	0.171	0.406	0.788	7.878	-439.20	73.71	
MDN GA All CV	3	98.15	1.84	33.02	66.97	0.170	0.403	0.775	10.662	295.75	1283.76	14h 2’ 54’’
		98.99	1.00	39.09	60.90	0.170	0.395	0.785	9.947	296.86	1284.87	

TABLE III. OPTIMAL MODULAR NEURAL & HYBRID NETWORKS OUT-OF-SAMPLE

Models		Active Confusion Matrix				Performance						Time
	Layers	0→0	0→1	1→0	1→1	MSE	NMSE	r	%error	AIC	MDL	
MDN NN	3	99.16	0.83	16.51	83.48	0.092	0.218	0.884	4.611	-1230.98	-943.03	26’’
MDN NN	4	98.99	1.00	16.51	83.48	0.095	0.224	0.880	4.859	-1130.80	-791.65	28’’
MDN GA All	2	97.81	2.18	15.59	84.40	0.105	0.249	0.866	6.775	-325.64	478.91	31h 47’ 21’’
MDN GA ALL CV	2	98.15	1.84	18.34	81.65	0.121	0.287	0.844	7.997	-890.26	-510.37	4h 55’ 46’’
		96.98	3.01	16.51	83.48	0.138	0.326	0.826	9.041	-803.90	-423.80	
MDN GA All	3	98.65	1.34	23.85	76.14	0.121	0.287	0.847	5.397	1610.55	3590.59	10h 33’ 20’’
MDN GA ALL CV	3	97.81	2.18	14.67	85.32	0.124	0.294	0.842	4.442	778.62	2215.05	16h 30’ 25’’
		97.15	2.84	11.00	88.99	0.116	0.274	0.856	8.239	726.97	2164.20	

INTELLIGENT SYSTEMS FOR BIOMASS PRODUCTION OPTIMIZATION WITHIN MULTI-TROPHIC INTENSIVE AQUACULTURE SYSTEMS BASED ON IMAGE PROCESSING METHODS

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1. INTRODUCTION

In the context of the requirements of fish farms to ensure the sustainable, medium and long-term development of fisheries and aquaculture, increasing the sustainability of production systems is absolutely necessary. Thus, the aquaculture production systems fulfil a dual role in order to achieve the previously mentioned outcome: they ensure the production of fish intended for human consumption, but also, actively contribute over time, to the activities of stocking and the repopulation of natural habitats. It is known that production systems and technological facilities in aquaculture are classified according to a multitude of technical, technological and ecological criteria. Among the many types of production systems, recirculating aquaculture systems offer the possibility of rigorous control of the technological process during the entire production cycle, with the aim of ensuring optimal growth conditions for the various fish species. As a result, considering the current concerns of diversification and intensification of aquaculture technologies, as well as those related to the recovery of bioresources from natural aquatic ecosystems, major investments are required for the realization of complex recirculating production systems. The high cost of fish produced in recirculating systems (Peirong & Wei, 2013) determines a multitude of technical and financial problems, which must be solved in order to ensure their competitiveness. In order to achieve them, the use of intelligent visual recognition and IoT techniques is proposed for the real-time determination of the growth parameters at the level of sturgeon and vegetable biomass, in order to optimize the applied technological management, respectively to improve the technical indicators of production.

2. MATERIALS AND METHODS

Object detection techniques using Computer Vision

Object Detection represents the problem of finding and classifying objects in an image into one of the categories of interest. Following the detection, a variable number of identified objects may result, which number may be different from one image to another (L. Liu et al., 2020).

An object is an entity characterized by a set of parameters (for example, the gray level of a pixel). Edge detection The Edge Detection method has been studied and implemented by many researchers using many algorithms. Bansal et al. (Bansal et al., 2013) review edge detection approaches. The choice of algorithm depends on the objective we have and the situations in which it will be used.

The texture of the material, the objects in the image, and the type of edge desired in response are factors that influence the approach chosen. We will stop at one of the most used approaches. The Canny edge detector (*OpenCV: Canny Edge Detection*, n.d.) which is probably one of the most efficient edge detection methods (figure 1).

Figure 1. The result of the Canny algorithm on a picture of a fish and a plant

This type of technique is based on gradients and histograms (figure 2). Gradients represent vectors oriented in the direction of the most significant color changes (Yuan & Liu, 2020). Initially, the technique was designed for pedestrian detection. The authors in (Dalal & Triggs, 2005) use the MIT pedestrian dataset. Step 1 calculates the magnitude of each pixel, step 2 calculates the oriented gradient for each pixel, and step 3 calculates the histogram of the oriented gradients.

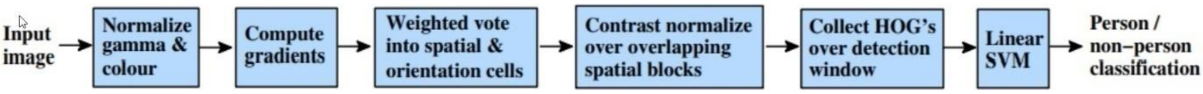

Figure 2. Feature extraction and object detection steps

Other traditional object detection methods are Viola Jones detector (Usilin et al., 2021), Histogram of Oriented Gradients (Ghaffari et al., 2020), Deformable Part-based Model (DPM) in (Xu et al., 2014).

Object detection techniques using Deep Learning

The problems and challenges related to object detection have seen significant progress in recent times. These were related to the variable number of objects in an image and the different sizes of the identified objects (Ketkar & Moolayil, 2021).

Another concern was to combine the two requirements for object detection (localization and classification) into a single model.

When analyzing an image we expect to identify objects that cover most of the image. Conversely, some objects could be variably smaller in size, overlapping, or even more in number. For this reason, it is necessary to do some image processing beforehand, which leads to increased complexity.

The problem of detecting the variable number of objects in images was approached using the sliding window. Basically, a fixed-size window is passed over an image and features are generated for all its positions. Some results obtained are removed and others are combined to get the final result. Finally, a border is drawn around the identified object.

Later, two-stage or region-proposal methods began to dominate. In two-stage methods, the first stage predicts a set of locations of all objects of interest where most of the background is filtered out. In the second step, a convent classifies the objects in these locations as background or one of the searched categories (Lu et al., 2021).

Region proposal methods produce much better results, but are too computationally expensive for real-time object detection, especially on embedded systems. YOLO (Redmon et al., 2016) and SSD (W. Liu et al., 2016) are architectures that aim to solve this problem by predicting the coordinates and probabilities of the bounding borders of objects in a single pass through the image network.

Instead, they are optimized for speed at the expense of accuracy. The accuracy problem was solved by (Lin et al., 2020) by resizing the loss function (focal loss). Thus, thanks to this improvement (RetinaNet), in addition to being faster, one-stage methods become as accurate as two-stage methods, allowing real-time object detection.

3. RESULTS AND DISCUSSION

In order to achieve the intended degree of sustainability and profitability, the multi-trophic aquaculture systems based on the integration of aquaponic techniques, require the optimization of the two growth technologies, for fish (figure 3) and vegetable biomass (figure 4), respectively. As a result, an intelligent system based on computer vision artificial intelligence techniques (deep learning) was developed for the real-time determination of fish biomass growth in order to optimize the amount of feed administered during the production cycle (figure 5).

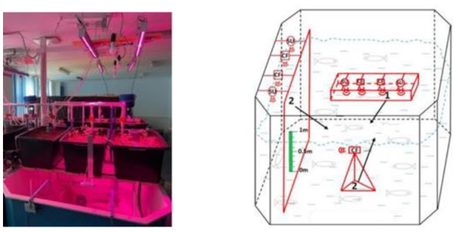

Figure 3. The AI monitoring system for fish biomass (CF – foto camera, SU - sonar)

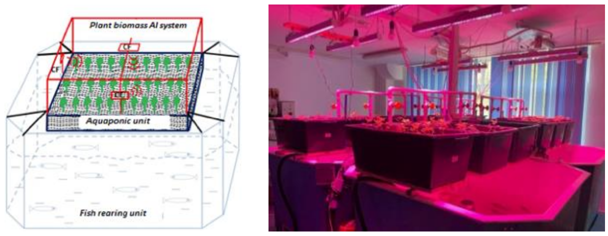

Figure 4. The AI monitoring system for plant biomass (CF – foto camera)

Also, the same technologies based on visual intelligence have been used to determine nutritional deficiencies as well as the growth rate for various types of plants (figure 6).

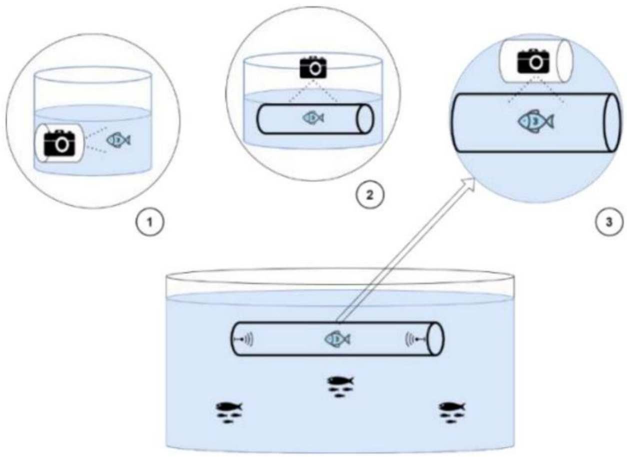

Figure 5: Fish detection system architecture

Figure 6: Plant deficiencies system architecture

The system implements a series of steps starting from choosing the type of neural network, collecting images for training in the format required by the network, followed by their processing and training the artificial intelligence algorithm. Finally, the formula for calculating the fish biomass and the amount of fodder will be established, respectively the identification of the various deficiencies of the plants. In summary, the system implements the following steps:

a) *Choosing the object identification algorithm in the image* - The task of the neural network will be to detect fish or plants in the images, returning a rectangular border with the position of the fish. The dimensions of the fish can be determined from this rectangle.
b) *Implementation of image segmentation - building a pixel "mask" for each object in the image, including the background* - This process returns many instances and objects that are not always of interest to us. Instance segmentation focuses only on certain objects in the image. The algorithm identifies only objects of interest in the image and creates the mask related to each object. There are several approaches to this task, approaches that have been synthesized by (Hafiz & Bhat, 2020).

c) *Building the data set and training the network* - This stage was influenced by the architecture of the fish and plant image capture system and the type of neural network chosen. Depending on the approach, the information contained in the images and the annotations are different. The process of processing images for training will be carried out using the established system. The number of images collected will influence the accuracy of the AI algorithm. For these reasons, it will be desirable to take as many images as possible. After the images are collected, they will go through a manual annotation process. For each image it will indicate the location of the fish/plants (through a border or mask) using specialized software. Finally, we will have a list of fish and plant images and annotations for each one. The purpose of this data set is its use in training the artificial intelligence algorithm intended to detect the sizes of the fish in the rearing unit.

d) *Implementation of the image classification algorithm for the classification of leaf surfaces using several labels that describe the different diseases they have*;

e) *Implementation of the image segmentation algorithm for fish identification*;

f) *Establishing the biomass calculation algorithm*: The last step was represented by the processing of the information obtained from the neural network. Calculating the exact size of a fish is a difficult process. The quality of the images taken by the camera is affected by the clarity of the water, the reflection and refraction of light, the degree of illumination of the pool. However, there is another technical factor that affects the detection of the distance to the object, and that is the error of the device. For these reasons, the determination of a fish development index, called the fish biomass development average, was taken into account. The system captures images of the fish in the pool, detects them and stores the images in the database. The number of images taken is not the same as the number of fish in the pool, as it is not possible to mark them. Consequently, it is possible to have a much larger number of photos than the number of fish in the pool. Also, some fish may not appear at all in the images. Information from the database will be extracted at a certain set period of time. The biomass development index will be calculated as the average of all fish detected in the previously collected images. The final result will be compared with the previous average to find out the degree of development of the fish. Based on these results, graphs are drawn during the development of the fish.

4. CONCLUSION

The traditional methods used to track the evolution of plants or fish are time-consuming, the automatic techniques, based on artificial intelligence, considerably reduce the monitoring activity. Using these methods involves acquiring images, extracting various features, choosing processing methods and analysing the results.

Neural networks can be used with the help of some programming scripts, the input data is sent to the server where the sizes of the detected fish will be calculated, respectively the deficiencies in plant development will be identified (classified). In order not to have problems with compatibilities, versions and libraries, containers will be created for each neural network, specific to each case.

One of the most important steps in an intelligent system for detecting the growth of fish biomass in an aquaponic system, respectively for identifying deficiencies in plant growth, is represented by the positioning of the cameras for capturing pictures, this step influences the quality of the images and the accuracy of the neural network

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IMAGE PROCESSING METHODS AS AN EFFECTIVE IDENTIFICATION AND DIAGNOSTICS TOOL

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1. INTRODUCTION

Continuous progress in the field of image recording techniques and the increase in the computing power of recently available processors have made image processing methods an essential part of technology and science. These tools are the equivalent of the human sense of sight. allowingmachines to interpret the world around them like that known to people.

Image processing consists of acquiring an image and converting it to a digital form (Tadeusiewicz, 1997) and (Woźnicki, 1997). Subsequently, the image is pre-processed, filtered and sharpened, as well as binarised. In the next step, the image is segmented and individual objects and their fragments (e.g., edges and other lines) are separated. These operations are followed by image analysis and determination of object features and information about their location, as well as image recognition and analysis (class identification). The main idea of computer vision is presented in Figure 1.

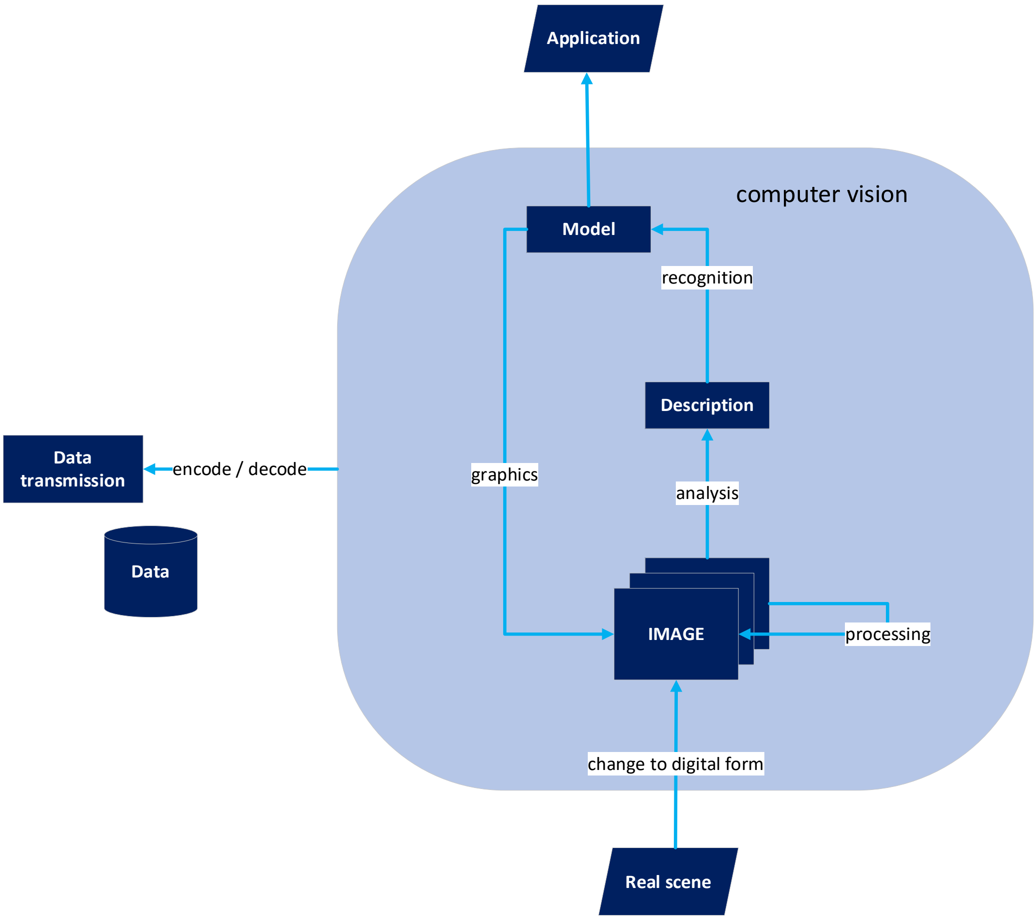

Figure 1. Processing of digital images

Classic digital image processing methods can be divided into the following groups (Tadeusiewicz, 1997): geometric transformations, point transformations (context-free), context transformations, spectral transformations, and morphological transformations.

2. APPLICATION OF IMAGE PROCESSING

Computer vision is a set of methods that, based on the processing of individual images or their sequences, attempt to analyze and describe the information contained in them, using, among other things, analysis of colors, shapes, lighting, specific features, movement, and many other relationships. Computer vision combines methods from many other fields, such as information technologies (e.g., graphics processors, parallel data processing, algorithmics), artificial intelligence techniques (e.g., machine learning, deep learning, pattern recognition), imaging (e.g., photography, medical imaging, thermography, stereovision), mathematics (e.g., signal processing, statistics, 3D geometry), automation (e.g., control systems, uncrewed aerial vehicles, robotics), neurobiology (e.g., imitation of the sense of sight and thought processes) or physics (e.g., optics, new sensors, imaging). The development in these disciplines translates into new possibilities in the analysis and interpretation of digital images, especially with the use of artificial intelligence tools in their investigation.

3. IMAGE ANALYSIS IN AGRICULTURE

Image processing methods are currently very widely used in agriculture. Economically efficient production of plants requires the use of precise tools and the accumulation of data, both historical and current, on the environmental conditions of the cultivation sites. Automating the plant cultivation process allows for a significant increase in cultivation acreages, which can be achieved using devices such as uncrewed aerial vehicles. Such a solution may allow for even 40–60 times acceleration of this process. In addition, UAVs do not require direct intervention in crops, as with traditional methods, i.e., using a tractor and other agricultural machinery, which destroy some plants and reduce the yield to some extent. In UAV solutions, the operator can plan a flight route, during which he can use the UAV as a data acquisition platform (Tomaszewski, 2021).

Another vision technology that can be used in agriculture is satellite imagery. These data are currently being recorded with the Sentinel-2 satellite launched into orbit under the European space program as part of the Copernicus terrain observation program. The original assumption of the satellite's operation was to support the services in monitoring forests and crisis management during natural disasters. This satellite records the image in 13 spectral channels (443–2190 nm), of which the most interesting from the agricultural point of view are the red edge channels, which can provide information mainly about the state of vegetation. The spatial resolution of imaging is 10, 20, and 60 m. The time the device flies again over the area is ten days.

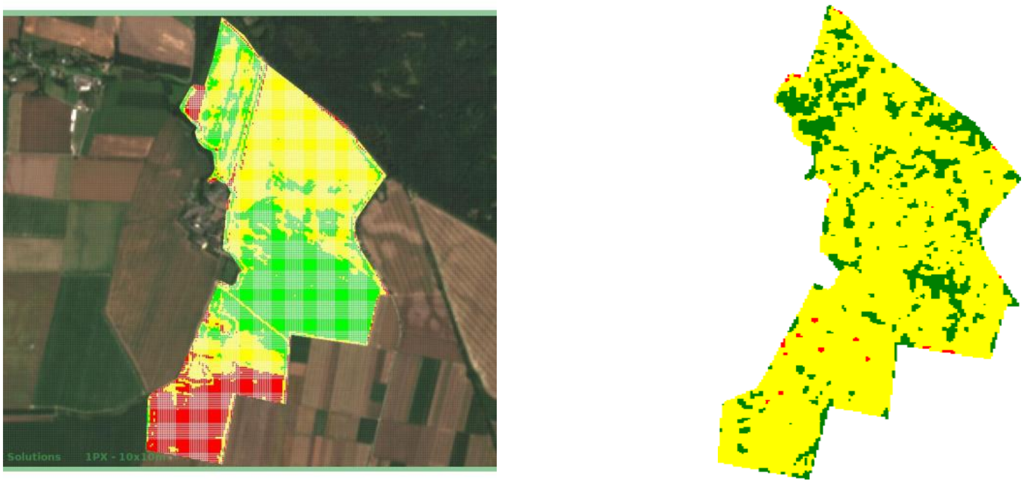

Figure 2. Change in the condition of crops determined on the basis of vegetation indices (Tomaszewski, 2021)

One of the basic directions of satellite image analysis is detecting changes occurring in the fields. It determines the differences in the land cover depicted in the photos recorded on two dates. The simplest method is visual interpretation, which makes it possible to find differences relatively quickly in a small area. In the case of large areas depicted in high-resolution photos, automatic tools are used to detect changes. Figure 2 shows an example of changes in the vegetation state, illustrated by comparing the images illustrating changes in the values of plant vegetation indices in a specific period. The yellow color means that the value of a given indicator does not change within the specified tolerance range. Red indicates a deterioration in vegetation, and green indicates its improvement.

4. IMAGE ANALYSIS IN THE POWER INDUSTRY

In recent years, there has been an increase in systems that use vision methods for motion analysis, three-dimensional measurement of object geometry, and automatic generation of three-dimensional objects based on photos. The significant development of fields supporting vision systems means that these systems are used as an easy-to-use, accurate and universal tool. The image is often an important and often the only source of information about the condition of the examined object (Rogério, 2016).

Among the vision systems, a large group consists of measurement systems based on optical measurement techniques. These systems are used in material and strength tests, especially in measuring deformations and stresses and in the measurement of kinematic parameters of objects.

The condition of the power line is assessed by performing scheduled visual inspections, which are performed at least once a year. During the inspection, the condition of supporting structures is checked - their foundations and fittings, the condition of insulators, connectors, electric shock, and overvoltage protection is also assessed. The supporting structures were selected as an element strongly exposed to all kinds of damage - both those caused by the operation of the line and those that are deliberate human activity. The most common damages in the case of lattice structures are missing elements caused by acts of vandalism, mechanical damage, and corrosion (Kuczkowska, 2010).

The most popular, and at the same time the least expensive, visual diagnostic method in the case of overhead lines is the registration of objects with cameras recording the image in visible light. The cameras used must have optics that allow for close-ups, which is because in the case of an inspection carried out from the ground, the distance to elements such as insulators, connectors, or the upper parts of the trusses is significant (the observation point from the object is often approx. 100 m). Visible light imaging is used to identify all types of damage to the truss, insulators and connectors.

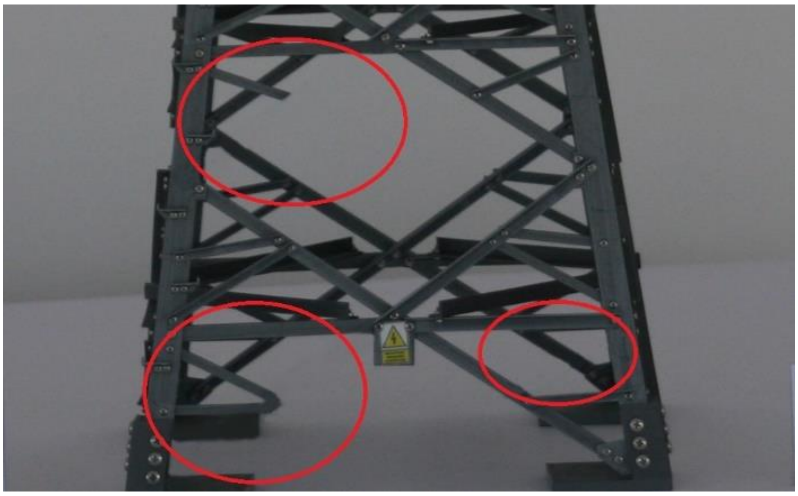

Figure 3. A fragment of a truss with marked gaps in the structure (Gasz, 2021)

a)  b) 

Figure 4. Result image of the developed method - a) deficiencies found (analysis), b) deficiencies found in the entire image (Gasz, 2021)

The diagnosis of the truss was performed while developing the virtual image method, which consisted in performing a comparative analysis of the image of the object taken with the image generated by the software based on the technical documentation at hand. Thanks to such a comparison, it is possible to find deficiencies in the tested object and other deviations in its structure in relation to the reference object (Gasz, 2021). The method is based on image recording operations, i.e., automatic matching of 2 similar but not identical sets of video data.

Isolators are another critical element in line diagnostics. In terms of their detection of digital images, work is currently underway using various methods. As an example, we can cite the method described in (Zhenbing, 2014), which is based on SURF (Speeded Up Robust Features) and IFS (Intuitionistic Fuzzy Set) algorithms. It allows locating insulators in aerial photos without pattern and segmentation. In the first stage, key features are searched for using the SURF algorithm, and then the obtained points are divided into a specific number of classes using the IFS algorithm based on correlation. If the correlation between the sets obtained is more significant than the set value, then both classes can be treated as sets of the same class. The insulator is identified based on the characteristic value of the shape factor.

Methods based on SIFT and SURF algorithms can locate an object precisely, but their application has some limitations (Li, 2010). Depending on the complexity of the background, they generate a significant number of significant points, which translates into an increase in computational costs. In the case of aerial photographs, insulators are most often found against a very diverse background. A previously created pattern is also required to locate an object. Another different approach to locating an isolator but using pattern matching is to segment the image into specific classes using the SRM (Statistical Region Merging) method and then convert the image to grayscale for histogram analysis. The histogram at this stage represents the individual objects in the image. The isolator is identified based on the pattern matching by correlation method (Michalski, 2018). This method, however, cannot cope with irregularities in the structure of the insulator and is sensitive to noise in the image. Another approach is to use SVM (Support Vector Machine) classifiers based on different feature vectors. In (Xian, 2016), the SVM algorithm was used to locate insulators based on the Gabor filter's features (Tomaszewski, 2018). Such approaches require a large number of samples needed to train the SVM classifier.

Figure 5. Examples of isolator detection

Currently, the deep technique is often used in the detection of insulators. The most common detectors based on convolutional neural networks, such as YOLO combined with networks used for classification, i.e., VGG-Net, obtain promising results.

5. CONCLUSION

Image processing is a valuable identification tool that can be successfully used in widely understood diagnostics. As shown in the examples in this article, these tools can be used for diagnostics of electricity infrastructure, as an effective tool supporting agriculture, and many others. This field is very developmental. Despite the significant progress in the development of artificial intelligence algorithms, which have opened new paths for image analysis, classical methods are still viral, especially in preprocessing tasks. According to the authors, this area offers new development opportunities. Therefore, the discussed examples of conducted research will be further developed to improve the accuracy of algorithms and the speed of analysis. The authors also plan to analyze images of other imaging bands and other applications, e.g. in diagnosing medical materials.

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THE APPLICATION OF MACHINE LEARNING METHODOLOGY AIDING AGRICULTURE MEASUREMENTS

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1. INTRODUCTION

Modern precise agriculture benefits from using large amounts of information. It comes from various sources, and its processing is becoming highly automated nowadays. The potential of machine learning algorithms comes in handy to provide the ability to consume all that data. There are many areas where this methodology is being applied, and measurement processes are one of them. Processes like field monitoring, crop prediction, and pathogen and pest detection are just a few examples of agronomic processes that could be significantly improved using machine learning algorithms, and the paper covers the utilization of several of them.

This short communication provides several examples of the current studies of vast agronomic problems. The full sets of results are already published for all of the presented cases, as well as the collected and annotated measurements that could be used to reproduce them. While collecting this data, some additional measurements have been taken, allowing one to extend this research.

2. SENSOR MEASUREMENTS MODELING

For the purpose of precision agriculture, the key is credible information. Getting a vast knowledge about the investigated cultivation raises a need to get many data points that could come from different sources. Those could be external sources, like weather services, that do not provide readouts from the exact location and usually use some estimates, thus offering limited data accuracy. On the other hand, it is possible to set up some own grid of measuring devices and get precise data from where they should be checked.

For the application that will be mentioned here, the information on the watering needs was important. The sensor network has been proposed to assess the exact location and amount of water that should be delivered to potato plants. For the investigated solutions, simple moisture sensors have been selected. Such a solution was not very expensive, but those sensors had some limitations. Each of those has to be calibrated and monitored during the whole season. Therefore the machine learning model has been evaluated for this case to ease this process.

Figure 1. An image of the investigated potato cultivar

The verification of that approach has been done using the set of the whole season measurements collected from the 24 different micro plots. To better test the model, two different potato varieties have been used, as well as different watering scenarios and different soil profiles, resulting in a pretty diverse dataset (Ruszczak, 2022, Deep potato, Mendeley data). The whole setup of this experiment and the detailed analysis of all investigated models has been widely described here (Ruszczak, 2022, Soil Moisture a Posteriori…). To boost the estimation power of the investigated models they were supplemented with data from the weather stations that were placed several meters from the plants and aimed at providing precise climate data. This experiment resulted in machine learning based regression models that allowed to decrease in the average error of those measurements from more than 2% to 0.8%, providing sufficient precision.

3. POTATO WATERING NEEDS ESTIMATION

For the purpose of managing large-scale farms and the increasing problem of droughts, the approach described below has one serious drawback. Due to the necessity of the many sensors application, it does not scale efficiently for large areas. And to tackle this issue, the employment of remotely sensed hyperspectral imagery has been studied.

The effect of such an application should be a map of watering needs that would be computed using the acquired imagery or a subset of those and would need additional sensor data for verification or initial calibration only.

As it is obvious at the stage of the experiment, besides the images that were collected using a hyperspectral camera (compact instrument *Zebra X1*, that provides sensing in the range of 450-900[nm] spectrum), the sensors readouts were also gathered. But this data was used only to train several different machine learning and deep learning models. This set of data was similar to the collection described in the previous chapter and collected at the same time.

Figure 2. Fragment of the acquired hyperspectral map (visible spectrum only)

For the conducted experiment, the images during the whole season were investigated. The resulting models that were trained with data from different vegetation phases resulted in various performances. Such modeling for remote root moisture measurements basing on leaf imagery varied from 0,60 to 0,80 in terms of the evaluated coefficient of determination (R^2), depending on the part of the season. The models were, at best, for the leaves that were still fresh and clearly visible on the images.

4. PLANT DISEASE DETECTION

Another popular application of machine learning modeling is plant disease detection. This is often made using deep learning models that are very handy at classifying different depicted pathogens. This could help in distinguishing the disease's event if the distinction of their symptoms is not obvious. For some plants, there are publicly available image sets that could be used to train models of decent performance. An excellent example of such a set could be the Plant village dataset (PlantVillage Dataset, 2019) which contains more than 60 000 images of several disease types for a number of plants. It provides a good base for such an algorithm development.

Figure 3. Image of infected tomato

The application that could be based on the algorithm trained on such a dataset could be used to detect pathogens using the images of plants that come from a similar stage of the infection. And that is usually late to prevent such infection from spreading. Thus, for the purpose of later investigation, another approach has been proposed. For the detection of pathogens, we checked the possibility of sensing them using hyperspectral measurements of the plants' leaves. Such a study should check which spectra. Also, those not visible and not captured using regular cameras are necessary to achieve this goal. We already published the preliminary results for the detection of the most frequent tomato threat, the Alternaria solani. For that pathogene we get the accuracy of its identification of 0.987 using ensemble machine learning models (Smykała, 2020). The study is continued in order to check if other pathogenes could be detected in the same fashion.

5. CONCLUSION

The selected machine learning models were set to showcase several different use cases of such methodology. Most of those experiments are in the early stages of ongoing research and are still being developed.

Most of the described experiments employ machine learning methodology to process the investigated data results with sorted and polished collections that could be a subject of further modeling. Our idea for this short communication is to share those datasets and encourage possible cooperation.

The last example we add here would be the aforementioned dataset of measurements made during the potato experiments (Ruszczak, 2022, Deep potato – The hyperspectral imagery of potato cultivation with reference agronomic measurements dataset…). Besides hyperspectral images and root moisture measurements, during the experiment, several other parameters were measured. Those were agronomic and physiological parameters that could be set against hyperspectral imagery or analyzed independently and led to develop some new remote sensing methodologies or to study of some other relations regarding collected data.

The parameters that were profoundly registered were related to the chlorophyll content of the plants, like chlorophyll fluorescence index, the maximum quantum yield of PSII photochemistry, and the performance of electron flux, but also figures regarding plant heights, number of stems, and their fresh and dry mass, leaf fresh and dry mass, number of tubers, tuber fresh and dry mass, starch content. Additionally, the leaf assimilation area, leaf area index, and relative water content for all collected samples have been calculated.

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MESH SEGMENTATION FOR HBIM APPLICATIONS

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1. INTRODUCTION

Rapid development in IT technology, Computer Vision, Photogrammetry, and Machine-Learning (ML) combined with off-the self-available reality-capture digital devices, such as Terrestrial Laser Scanners (TLS), UAVs and Mobile Laser Stations (MLS) have contributed significantly to widespread adoption of Building Information Modelling (BIM) in the field of Culture Heritage (CH) and Conservation. BIM consists of a process for cross-referencing tangible and intangible information on a 3D reality-based model, allowing thus for scientists and stake holders, across different disciplines and fields of expertise to access, validate and contribute in a robust and efficient multimodal manner (Grilli et al., 2020; Pocobelli et al., 2018).

BIM, especially in its reversed engineering form that is required in CH and Conservation applications, begins with a 3D reconstruction of the site. This first fundamental step aims at capturing as much detail as possible in what is called a 3D point cloud (Moyano et al., 2021). Modern 3D reality capturing devices utilized in parallel with commercial BIM platforms can easily render complex organic 3D geometry but still have not been optimized for non-tangible information integration (Pocobelli et al., 2018).

3D data acquisition at large scale applications deploy both Terrestrial and Aerial methods (Martínez-Carricondo et al., 2020; Matrone & Martini, 2021). In TLS, such as Faro X130 or hand-held devices, Artec EVA 3D (Moyano et al., 2021), carrying both RGB camera sensors and LiDAR technology, output is fused with dense point cloud produced from aerial photogrammetry through Structure-from-Motion/Multi-View-Stereo algorithms (SfM/MVS) (Mania et al., 2021; Moyano et al., 2021). Well established ground stations, such as TLS, outperform their aerial counterparts in term of resolution, accuracy and processing speed whereas SfM UaVs' based schemes eliminate the need for scaffolding and ease access to isolated, hazardous and hard to reach locations (Antón et al., 2018; Martínez-Carricondo et al., 2020).

BIM keeps producing promising results in the field of Cultural Heritage and Conservation (Khalil & Stravoravdis, 2019; Rodríguez-Moreno et al., 2018; Valero et al., 2018). Barrile & Fotia, (2022) emphasize on the ability of BIM to serve as an archive for historical documents contributing to asset's management. Mania et al., (2021) utilized HBIM and 3D surveying techniques for uncertainty "quantification", which is a dimension inherently interconnected to heritage and conservation. They exploit BIM and 3D reality visualization of commercially available packages in order to virtual reconstruct the true location for the metopes decorating Athenian Treasure at Delphi. Abbate & Invernizzi (2022) explored semi-automatic processes for HBIM-to-FEM simulation structural analysis. FEM prerequisites water-tight volumetric objects, representing initial ground-truth geometry (Barsanti et al., 2017).

Regardless of the foreseen growth of HBIM, two prominent factors often bottleneck its wide-scale integration, 1) the non-uniformity of heritage sites (Pocobelli et al., 2018) and 2) the inefficiency of commercial BIM CAD-driven platforms to decompose building components down to stone accuracy (Ibrahim et al., 2020; Idjaton et al., 2021a; Isailović et al., 2020; Nalpantidis, 2021; Thomson & Boehm, 2015). Therefore, in this paper an innovative and quite robust methodology is presented, which introduces Singular Value Decomposition (SVD) for 3D scanning leveraging though stone accuracy decomposition of ancient Doric columns. The proposed algorithm will be validated on 3D point cloud data extracted from Apollo's Temple reality-based model at Delphi which was at our disposal (Fig.1).

Figure 1. Orthorectified 3D model projection of the Apollo's sanctuary at Delphi

2. MATERIALS AND METHODS

As stated above the main objective of this effort was to develop a new approach for stone-level accuracy segmentation of objects that don not necessarily conform to planarity or verticality constrains. The algorithm disclosed operates on both point clouds and/or textured meshes. Implementation methodology is divided into 6 individual steps:

1. Create a vertical grid along the Z-axis and extract point cloud data for each incremental step
2. For each given set of data define a horizontal plane using SVD (Muller et al., 2004)
3. Project XYZ data onto the hyperplane estimated at step
4. Transform to polar coordinates and best-fit data using least square fitting
5. Trace back fitted models and extract radius and center for each cross section
6. Estimate locations of abrupt decline in column's radius

SVD algorithms consist of a major chapter in Computer Vision and experience great popularity especially in image recognition applications (Chen, 2018; Li, 2016; Muller et al., 2004). Herein, SVD is utilized in order to overcome normality assumption. Sampling resolution will also need to be tackled in a pre-processing stage, since this will have a great impact not only on the scanning accuracy but also on the success of convergence of SVD fitting algorithm. Scanning resolution is expected to fall within the range of five to one centimeter.

3. CONCLUSION

Future work will seek to explore the applicability of the proposed approach on real test data comprising of six stone pillars extracted from a 3D model of Apollo's sanctuary at Delphi (Fig. 1). Stone-by-stone segmentation (Idjaton et al., 2021b; Nieto-Julián et al., 2022) and BIM primitive extraction (Banfi, 2019; Garagnani & Manferdini, 2013; Yang et al., 2019) still remain open issues attracting a lot of scientific research. Here the proposed algorithm might provide a versatile alternative to segmentation automation endeavors contributing thus the fastest growth of the HBIM scientific research sector.

4. ACKNOWLEDGMENT

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The implementation of smart technologies in luxury hotels Evidence from South Korea

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Abstract
Numerous of hospitality enterprises around the world either have already adopted or they start to adopt smart technologies in most departments of their functioning. However, the extent Smart Technologies application in hospitality industry generates new questions and hesitations concerning matters of sustainability, alienation and employability. South Korea, a country with a gradually noticeable growth in tourist flows until 2019, was chosen for the conduct of the present research. Unfortunately, the outbreak of coronavirus pandemic resulted in a deep drop of arrivals. The objective of the research is to identify the diffusion extent of smart technologies in different departments of Luxury and Upper Upscale hotels in South Korea and to depict in which ways smart technologies have contributed to the efficiency and sustainability of the particular type of hospitality enterprises. Semi-structured interviews with open-ended questions were conducted for the collection of data.

The responses revealed that smart technologies in Luxury hotels of South Korea are “conditio sine qua non” for the operation of all the departments. Interviewees supported that smart technologies enrich guests’ experiences and increase guests’ satisfaction by offering to them alternative opportunities for in-room entertainment and recreation. Luxury and Upper Upscale Hotels always pursue to keep up with advancements in Smart Technologies with the aim to prevail in their guests preferences. However, the estimations about the influence of Smart technologies in guests’ intention for revisiting are controversial. The personnel of Luxury hotels are favorable to smart technologies, especially the new-hired employees. Luxury Hotels are seeking the investment in Smart Technologies which contribute to the efficient monitoring of energy and water consumption. Smart technologies have a valuable role in Customer Relation Management even if their impact in tourist inflows recovery remains blurry. Executive managers believe that Smart technologies can offer a wide range of possibilities for sustainable development in the hospitality industry of South Korea.

Keywords: Smart technologies, South Korea, luxury hotels, sustainability

INTRODUCTION

Ambient Intelligence has rapidly converted the landscape of the tourism industry by introducing innovative and alternative ways of hospitality management and customers’ services. Rehse et al. (2020) argued that the components of contemporary technologies facilitate the hospitality enterprises to be more a) predictive, which means, capable to predict their customers’ needs, b) preventive since new technologies advocate businesses to minimize occurrences of errors and c) proactive which means they will manage in a satisfactory degree to enrich the hospitality experiences beyond their guests’ expectations. Furthermore, digital technologies enable customers to have an active role regarding the formulation and the components of their accommodation experiences. As a consequence, many hospitality enterprises around the world either have already adopted or they start to take advantage of smart technologies in most departments of their functioning since the features of Smart technologies, namely flexibility, instant correspondence and adjustment through networks and interconnections among related devices, combined with cost-efficiency, offer a competitive advantage towards the conventional hospitality enterprises (Jaremen et al., 2016).

On the other hand, the extensive application of Smart Technologies in the hospitality industry generates new questions and anxieties concerning issues of privacy and data leaks, the inflexible recovery of automatic system failures as well as the influence in the rates of unemployment, since it is estimated that 25% of the hospitality workforce will be replaced by smart devices and humanoid robots until 2030 (Millauer and Vellekoop, 2019; Tussyadiah, 2020; Khaliq et al, 2022). They have been expressed arguments that the excessive use of smart technologies services instead of personnel in hospitality sector, not only confines human contact and communication and intensifies social isolation but also elicits indifference towards the welfare of societies and cultures of travelers' destinations (Tussyadiah, 2020; Khaliq et al. 2022, Li et al, 2021).

The paper is divided in six parts: The first part presents a brief review of previous studies about the relation of electronic engineering and information technology with hospitality. The second part refers to the social and community context of the study, that is to say, the hospitality business in South Korea, the objective of the study and the research issue. The third part describes the sample of the research as well as the methodological framework. The forth part displays the findings of the research and the fifth part contains a discussion upon those findings. Finally, the sixth part indicates limitations and proposals for further research.

LITERATURE REVIEW

One of the most valuable feature from the implementation of Ambient Intelligence is that enables potential customers and guests to get served twenty-four hours per day with efficiency and punctuality (Citak et al, 5). For example, chat bots and interfaces, with the form of platforms, enhance immediate responses to customers' questions and foster prolific dialogue among hospitality partners so as to ensure positive results from customers' aspects. It was also revealed that customers appreciate the time- saving procedures which are endorsed by smart technologies, such as self-service check-in and check- out, an evidence which was also confirmed by Chang et al. (2022) when the question comes to the connection between time-saving acts and guest perceptions on experiential quality.

According to Pillai et al. (2021), the evolution and implementation of Smart technologies have created new orientations and challenges for the tourism enterprises. From the aspect of provided services, it enables less contact among front-line employees and guests, emphasizing in the crucial matter of hygiene, safety and social distance preservation, along with the fulfillment of personal requirements of each guest. It is a consensus that during the outbreak of Covid19 pandemic, smart technologies were proved to be a valuable mean for preserving high standards of health protection for guests and for hotels' staff as well, augmenting thus the sense of safety, especially in unmanned hotels (Chang et al, 2022; Li et al. 2021). For instance, visual guides or robots providing delivery services, guiding and consulting to customers or cleaning services and disinfection in hospitality premises, have contributed a lot to the confinement of covid19 spread in conjunction with the performance of high quality services (Li et al., 2021). From the perspective of safety in hospitality industry, except from touchless transactions, smart technologies have also improved food safety via smart food labels and sensors which scan for diseases and assess the freshness of edible products (Chang et al. 2022).

Moreover, the use of smart devices and tools allows the generation and collectiveness of data which provide useful information concerning food waste management and controlling energy consumption, whereas the increasing use of big data has led to the improvement of revenue management software providing thus hospitality entities with more accurate forecasting which results in more realistic and efficient pricing policies (Chang et al., 2022; Millauer and Vellekoop, 2019). The progresses in Artificial Intelligence and robotics have created new opportunities for hospitality suppliers to perform marketing strategies in a vast array of potential customers. Indeed, marketing departments of hotel chains are now equipped with more effective tools which enable them to predict and offer a variety of services, tailored to customers' different needs, goals and wishes, from pre-trip to post- trip stages (Tussyadiah, 2020).

Unmanned hotels have also begun to gain a foothold in customers' preferences, offering to them a combination of independence and personalized service through the utilization of Smart technologies. Guests of smart hotels can arrange the temperature of their rooms or bed mattresses and curtains opening by voice commands, can access information, can order, get served or interact with assistant robots and smart devices without seeking for assistance from direct service employees (Chang et al., 2022).

However, some guests' categories are not familiar with the computer and automation technologies and they do not feel confident enough to use them (Tussyadiah, 2020). For these guests, the introduction of smart technologies is a source of inconvenience which discourages them from choosing a smart hotel for their accommodation, especially in cases where customers' needs require a high level of empathy (Ayyildiz et al., 2022; Khaliq et al, 2022). It is also supported by relevant studies that even when guests are favorably disposed towards robotics and smart technologies in hospitality sector, they still prefer services delivered by the human staff (Ayyildiz et al., 2022; Choi et al, 2020). Though, those findings are in contradiction with the results of Belanche et al. (2020) study where it is claimed that customers' perceptions of affinity with human-liked service robots is increased and boosts the recommendation of these services in social media.

CONTEXT AND RESEARCH QUESTION

South Korea was selected to conduct this research because it is recognized as one of the world's leading nations in research and development with great progress in various divisions of technology, such as automation, industrial design and manufacturing, robotics, smart devices, semiconductor materials and so on. The industrial and technological achievements of South Korea are widely applied in the daily activities of the inhabitants who are accustomed to innovative applications and devices (Dayton, 2020).

In the field of tourism industry, South Korea had a noticeable growth in tourist flows with 17.5 million international arrivals in 2019 (Jones Lang LaSalle, 2021). Unfortunately, the outbreak of coronavirus pandemic resulted in a deep drop of arrivals (approximately 976,000 arrivals in 2021), especially from the target- market of China, which is the main source of tourists' inflows in South Korea (Fig.1).

Despite the low travelers' rate, it is expected that tourism industry in South Korea will recover in the near future since USD 1.4 billion had been invested in hotels in 2021. It was also noticed that Luxury and Upper Upscale hotels of South Korea are recovering much faster comparing with Midscale and Economy hotels (Jones Lang LaSalle, 2021). In particular, the Revenue for Available Room indicator for Luxury and Upper Upscale hotels showed a recovery rate close to 86% from January 2020 to December 2021, when the same indicator for Midscale and Economy hotels hovered at about 66% (CoStar, 2022).

Taking into account the aforementioned, the question that arises is the following:

How smart technologies have contributed to the efficiency and sustainability of Luxury and Upper Upscale hotels in South Korea?

The pursuit of this question is to identify the diffusion extent of smart technologies in different departments of Luxury and Upper Upscale hotels in South Korea and to depict the benefits and difficulties that those types of hospitality entities have to deal with concerning the application and effectiveness of smart technologies.

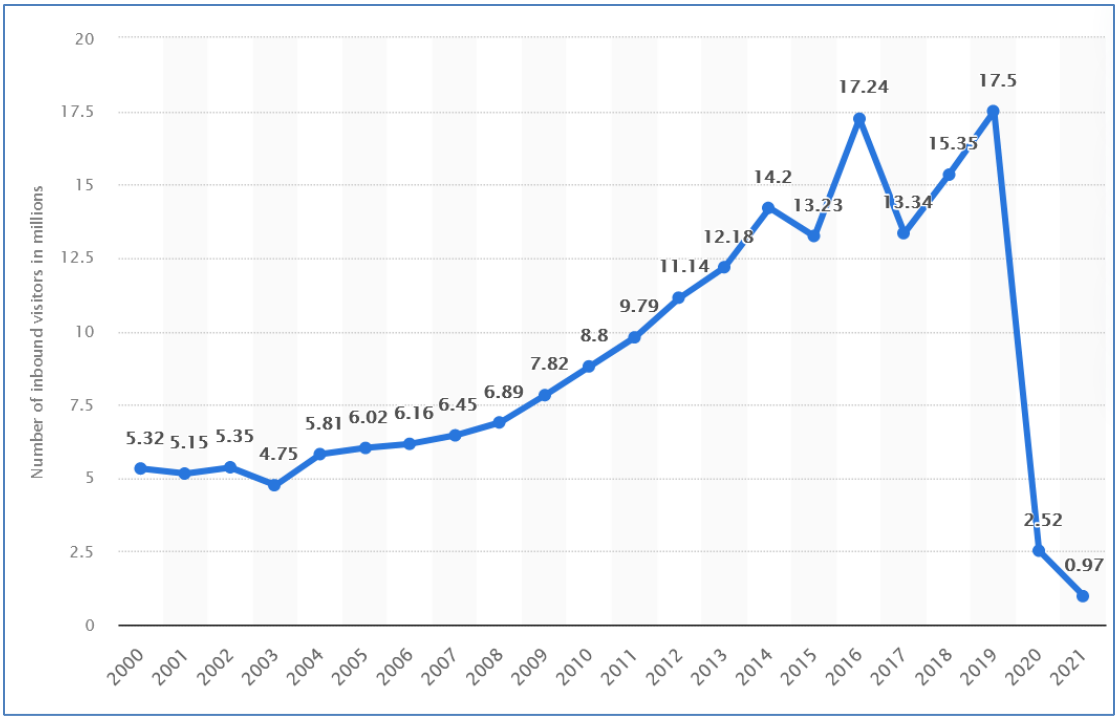

Figure 1: Number of inbound visitors to South Korea from 2000 to 2021 (Source: Statista Research Department, Feb. 2022)

MATERIALS AND METHODS

Qualitative research was preferred in the specific study since the goal of the researchers is not to confirm predetermined findings rather than to explore in- depth a phenomenon which is rapidly spread among the hospitality and tourism businesses and has caused controversial reactions.

Semi- structured interviews with open- ended questions were conducted for the collection of data. As for the sample, executives from Luxury and Upper upscale hotels participated in the research as interviewees. Researchers pledged to maintain confidentiality concerning the interviewees' identities and the brand names of hotel enterprises that are involved in the study.

Main questions of the interview

The following questions comprise the structure of the interviews. The questions are predetermined, yet the interviewers had the discretion a) to give further explanations to the participants for the content of each question, b) to express it in a different way in order to make it more comprehensive, c) to add clarifying questions whenever was necessary.

1st: What forms of Smart Technologies are encompassed in the various departments of the hotel?
(The purpose of this question is to identify in what extent Smart technologies are integrated in the general context of Luxury and Upper Upscale Hotels in South Korea).

2nd: To your mind, have Smart Technologies- applied at your hotel- created added value to your hospitality product? Please, justify your answer.
(By this question, researchers tried to explore if and how Smart Technologies in Luxury and Upper Upscale hotels enrich the attributes of hospitality services in ways that increase the perceived value).

3rd: How do you think that Smart technologies affect guests' satisfaction? Please, justify your answer.

(This question constitutes an attempt to disclose if Smart Technologies are a factor of vital or minor significance in guests' satisfaction).

4th: According to your knowledge, what is the impact of Smart technologies on guests' intention to revisit the hotel or to recommend it to potential customers?
(Repeated customers and word- of- mouth advertising by satisfied guests are significant clues of a successful hotel policy; thus, it is important to be specified how Smart technologies reinforce these clues).

5th: What's the perception of Smart technologies in front-office and back- office employees?
(Productive employment and decent work are considered as substantial goals for the establishment of sustainable enterprises. It is interesting to exact how these goals are supported by smart technologies in Luxury and Upper upscale hotels in South Korea).

6th: In what ways Smart Technologies have affected the relation of the hotel with the environment?
(The purpose of the particular question is to examine how Luxury and Upper upscale hotels in South Korea manage, through Smart technologies, to combine exquisite experiences with environmentally friendly practices).

7th: How Smart technologies will help hotel to overcome the negative effects of tourism inflows reduction in South Korea?
(Since tourism industry in South Korea was heavily affected by the epidemiological crisis of coronavirus, the role of smart technologies is necessary to be investigated as regards the revival of hospitality sector).

8th: How do you think that smart technologies will affect the hotel performance in the near future? Please, justify your answer.
(The aim of this question is to depict: a) how Luxury and Upper Upscale hotels in South Korea can take advantages from the potential of Smart technologies so as to improve their performances in the upcoming years, b) how they can detect and handle the risks that stem from the use of Smart technologies in the particular hotel entities).

FINDINGS

According to the responses given, smart technologies in luxury hotels of South Korea are "condition sine qua non" for the operation of all the departments. The most common usage of smart technologies are the chat bots in call centers, the remote meeting platforms in banquet rooms, blue tooth speakers in rooms, QR codes for restaurant menus, the digital flipcharts, the POS systems, digital registration systems, Liquid Crystal Display (LCD) digital artworks in lobbies or corridors and so on. For the Sales and Marketing departments, the integration with messaging applications, such as KAKAOTALK, is one of the most popular keys for upselling techniques and product positioning. For the particular departments, smart technologies proved a vital tool during periods of no physical contact enhancing the visibility of hotels and increasing the reach of the marketing. Luxury hotels of South Korea have also adopted digital task assignment systems and software in order to upgrade the internal communication and the inspection procedures among different operational departments.

Respondents claimed that, since domestic tourists in South Korea as well as tourists from Japan and Malaysia are intimate with the use of smart technologies in general, smart technologies integration is considered as a prerequisite for achieving high standard in hospitality services. They supported that, in a tech driven country as South Korea, the impact of Smart Technologies in perceived value is crucial, especially for young- aged guests and business travelers. As they have stated, in regards with their customers' feedback, Smart technologies contribute to well- rounded encounters with less effort and time-spending from guests' side, which in turn, enrich guests' experiences and increase guests' satisfaction by offering to them alternative opportunities for entertainment and recreation (e.g. in-room virtual guiding visiting). A participant referred that *"(..) guests' satisfaction from hotel services is attributed to smart technologies, even if guests are not aware of this"*.

Regarding the intention of revisiting a hotel or to empower word of mouth advertising (lately it is referred as "word of mouse", stating that tech and social media have replaced the human contact), received answers were not exactly in the same direction. Luxury and Upper Upscale Hotels always pursue to keep up with advancements in Smart Technologies with the aim to prevail in their guests preferences and ensure their guests' revisiting. Some participants supported that Smart technologies constitute a competitive advantage in the luxury segment and are widely used from marketing departments of Luxury Hotels not only for new customers' recruitment but also for guests' retention. Other participants are more skeptical about the decisive role of Smart technologies in revisiting intention. They argued that Smart technologies are considered as necessary components for the majority of business entities in any case; as they claimed, the society of South Korea is accustomed to the use of digital items so, even though the implementation of Smart technologies in hospitality businesses contributes to guests' satisfaction, they are not sure that smart technologies are included in the main lures of Luxury hotels.

All the respondents shared the common opinion that the personnel of Luxury hotels, either they are back office employees or front line staff, are favorable to smart technologies. This positive stance is justified since the accomplishment of daily tasks and duties are getting easier and employees become more productive with less effort. Except from the prolific results to their performances, employees also appreciate the contribution of smart technologies in their professional training, especially the new-hired. With remote training and virtual sessions, Luxury and Upper Upscale hotels give the opportunity to the new- hired staff to counterweigh the lack of experience with professional knowledge, eliminating the probabilities of errors occurrences and misunderstandings. The more experienced employees are also benefited from smart technologies from the aspect of vocational training, since they are always informed about state of the art advancements in hospitality sector. Interviewees claimed that smart technologies are consider as a valuable mean for job seekers in hospitality industry whereas the Luxury and Upper Upscale hotels in South Korea use mostly smart technologies for the recruitment of personnel than face to face interviews. In a nutshell, employees of luxury hotels do not consider the extensive implementation of smart technologies as a job threat- on the contrary, they look for it.

Concerning the environmental issues, Luxury and Upper Upscale Hotels are seeking the investment in Smart Technologies which contribute to the efficient monitoring of energy consumption with the aim of decreasing the energy expenditures in the long run. The adoption of Smart technologies has also lessened the in- room water waste as well as in housekeeping and food and beverage departments. Minimizing paper waste has been proved also beneficial for the natural sources and for the reduction of operating cost. For example, during the conduct of an interview, the participant mentioned: *"Less printing! (..) Digital info, like menus, is easy to adjust without the need to reprint it"*. Only one interviewee expressed his doubts about the importance of smart technologies in the environment, or – to express it more properly- about the motives of implementing smart technologies for the benefit of the environment. He supported that, even though the application of Smart technologies is beneficial to the environment, the reason of adapting them stemmed from the need for cost reduction rather than from pure environmental concern.

There wasn't unanimity among the respondents about the role of Smart technologies in confronting the noticeable decline of tourists' inflows in South Korea. Some participants pointed out the importance of Smart technologies in Customer Relation Management. In particular, they mentioned that Smart technologies allowed marketing and guest relations departments to preserve the contact with prior customers, namely former guests from China, while they enhance the entrance of Luxury hotels in new market segments. Other participants argued that Smart technologies have not much to offer for the resolution of this situation. However, all the participants agreed that the landscape in Korean hotel market still remains blurry for this year, so they are in pending of seeing the impact of Smart technologies implementation in tourist inflows recovery.

Finally, respondents agreed that Smart technologies can offer a wide range of possibilities for sustainable development in hospitality industry. Since technology evolves, Luxury and Upper Upscale hotels of South Korea work intensively on becoming more digitalized regarding the offered services and the operational administration. Respondents expressed various proposals about the implementation of smart technologies in many sectors of Luxury Hotel Businesses, such as provisions of alternative e- commerce services or with the form of credit to efficient employees. After the outbreak of covid19 pandemic, hoteliers of South Korea count on smart technologies to cover the growing demand for delivering untact services and complying with the safety protocols. Luxury hotels invest in virtual databases, where store and retrieval of data is ease with the aim of adjusting services in guests' special needs and preferences and offering more personalized leisure experiences. Interviewees agreed that the integration of smart technologies has improved the performance of Luxury hotels. Though, Smart Technologies have not been applied with the same way for each department. A few hotels pursue the integration of smart technologies which improve cost control policies whereas other hotels invest mostly to the use of smart technologies which augment their sales. Some of the interviewees expressed their anticipation of seeing how virtual reality will be combined with hospitality services in the future.

DISCUSSION AND CONCLUSIONS

Luxury hotels in South Korea were proved to be more resilient in covid19 financial side effects than other hospitality businesses due to the widespread implementation of smart technologies in their operation modes. They became more flexible and adaptable to the new health and safety protection requirements, which counted a lot to guests' perceptions. They managed to ensure better working conditions for their staff and more career opportunities for younger job-seekers. Smart technologies facilitate the rational allocation of revenues in Luxury hotels function and the decision making processes from the managers' perspective. Responsible consumption of paper, water and energy has been achieved in a remarkable degree from Luxury hotels because of smart technologies' integration.

The aforementioned associated directly with four of United Nations Sustainable Development Goals, which included in the Agenda of World Tourism Organization. The goals are the followings (World Tourism Organization, 2016):

Goal 4th: Quality education. With the use of Smart technologies, Luxury hotels in South Korea managed to offer opportunities of vocational training to their workforce so as to provide them with new skills and professional knowledge.

Goal 8th: Decent work and economic growth. Smart technologies contribute to the economic growth of Luxury Hotels, which in turn creates new jobs in hospitality sector. In addition to this, employees, with the assist of smart technologies, spend less of their working hours in the accomplishment of repetitive tasks so they have more time to be more creative and to focus on customer centric services.

Goal 9th: Industry, Innovation and Infrastructure. Luxury hotels have taken advantages of Smart technologies usage and they have renovated their infrastructure so as to be proactive and adjustable in new challenges.

Goal 12nd: Responsible Consumption and Production. The rational consumption of natural sources, such as water and paper, is attributed in the implementation of smart technologies and therefore results in a more efficient operation of hospitality businesses.

The financial cost of cutting edge Smart technologies is not affordable for all the hospitality enterprises of South Korea. However, Smart technologies are an investment which yields short and long- term profits and improves the performances of hospitality businesses. Contrary to the findings from other studies about the precariousness of workforce due to the extensive usage of Smart technologies, for employees of Luxury Hotels in South Korea, the integration of smart technologies is not appraised as a menace but as a virtue. It would be interesting for the stakeholders of hospitality industry to find ways so as to get more benefits by Smart technologies potential in the future.

LIMITATIONS AND PROPOSALS FOR FURTHER RESEARCH

There are several limitations in this research, which led to proposals for new studies. The first one concerns the social context of the research. South Korea is a country where citizens are favorably disposed towards technological innovations and Smart technologies are part of the daily flow of business. It is normal then Smart technologies to be included in the daily operation of Luxury hotel departments. Though, in other countries or societies, the embedded technologies may not bring the same results as in the case of South Korea.

Secondly, the research focused on Luxury and Upper Upscale hotels since they are one step forward in the adoption of advanced technology compared to Midscale and Economy hotels. Therefore, they can get easier the outcomes – positive or negative- from the implementation of Smart technologies and to adjust their policies. So, scholars could explore the impact of Smart technologies in other hospitality segments in terms of efficiency and sustainability.

Thirdly, the participants are executive managers who have the overall picture of the hotel functioning and of their departments as well. It would be interesting however to investigate directly the opinions of the staff who work on the front line or on the bottom stage, e.g. chambermaids or waiters.

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In-time outline of earthquake cataloguing and intelligent systems deployed for decoding the behavior of distinct seismic zones

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INTRODUCTION

This technical approach discusses earthquake cataloguing in time and analysis methods using AI focusing on the behaviour of potential distinct seismic zones. This document is itself an example of listing these different types regardless of how far these methods can go, each with its limitations, and ultimately how deep learning tries to find a new way and perspective of solving such seamless unsolvable complex problems.

This extended abstract discusses earthquake cataloguing from the archeological era till today and different types of various intelligent methodologies, classified according to the Epoch when they appeared, what they achieved, such as early solutions and how further advances in heterogeneous parallel processing helps to “dig deeper” using extensive multilayer deep neural networks.

AI systems used in the task along the way include rule-based and case-based expert systems, artificial neural networks, machine learning and lately parallel processing deep neural networks along with Big Data mining techniques and stochastic statistical methods that can approach long-lasting seamlessly unsolvable problems. This study focuses on comparing between these different techniques and various tools used. Based on these previously obtained results, it recommends developing a Deep Learning neural network for associating earthquakes to particular underground faults falling within possible distinct seismic zones.

1. The First steps of written Evidence – Archaeological

Seismic activity in the Greek Aegean Region (region of our Interest and base of this study) provides a lot of valuable seismic data thanks to the shifting plate boundary from submerging of the African plate under the European plate. This gives this region a huge number of countable and several big earthquakes. The first significant references about seismic occurrences in the archaeological literature describes in a detailed way the destruction of cities and buildings of which is likely to relate to natural catastrophic events, such as earthquakes, landslides, or even volcanic eruptions. Often the after fall of this Archaeological evidence is until today measurable and viewable. The first attempts for a countable measure were made by the ancient Greek Philosophers such as Aristoteles, Theophrastus, Eratosthenes, Plinius, Stravon etc.
Archaeological evidence of disasters combined with this written information often indicate seismic activity and can provide useful information to geologists, seismologists and engineers for active geological processes and seismic facts. The limitations to these sightings were that the data wasn’t detailed and often of incorrect value.

2 Renaissance, first steps of Real Data Acquisition

During the Renaissance and early Industrial Revolution, the time period when the human mind began starts to work more on sciences and reliefs from the spiritual god centric point of view, we see the first steps in gaining access to data and slowly to raise the head and observe in a more reliable way this phenomenon. Great steps were made because it is the first time that from observations, we went to earthquake records and the beginning of studying more intense.

3 Industrial Revolution the true size begins to reveal itself

Prior to the development of the magnitude scale, the only measure of an earthquake's strength or "size" was a subjective assessment of the intensity of shaking observed near the epicenter of the earthquake. Many scientists raced to develop and categorize the seismic intensity. For the record the first scales appear by Rossi-Forel in the late 1880’s. In the 1920’s Harry O. Wood and John A. Anderson developed the *Wood–Anderson Seismograph*, an instrument for practical record the seismic waves. This makes him to lead a team to develop a network of Seismographs in the region of California and so to give a closer look for science. In his team he had also recruited a young Charles Richter to measure the seismograms and locate the earthquakes that generate the seismic waves. Until 1902 the measurements were made under the known Mercalli scale. He founded a system for classifying earthquakes using the well-known Roman Numbers from I to XII (I small shock to XII big catastrophic earthquake). The obvious problem with the Mercalli scale was that it relied on subjective measures of how well a building had been constructed and how used to these sorts of crises the population was. The Mercalli scale also made it difficult to rate earthquakes that happened in remote, sparsely populated areas due to less high and complex buildings. So, Richter developed a counting system which uses the results on a seismograph. The intensity of the suspension of the needle on the pendulum in addition with a marker and a winding rolled paper gives us the long-waited results to have on paper and in a recorded way the necessary data of an Earthquake. He also had the possibility to show the center of the Earthquake which he called Epicenter and also a countable in details a metric system with a logarithmic bases which he called magnitude. For example, an earthquake of a magnitude 7.0 is ten times stronger than 6.0 and 100 times stronger than a 5.0 and 1000 times stronger than a 4.0. This Richer scale that we use still nowadays was published in 1935 and became instantly very famous throughout the globe.

4 The era of Information Technology

With the beginning of the era in Information Technology mankind made huge steps in evolving the necessary knowledge from the classical physics and mathematics into new technology in the era of computer science. Artificial Intelligence began to appear in modern science and especially formed a new topic which simulates all the physical activities into raw data and algorithms. The era of modern Neural Networks was born. We figure out which are the next steps for implementing this to our favor.

The first attempt was made with this software to see how deep we can analyze the problem and how far we can go with a simulation in this solution problem we implemented all the necessary libraries to simulate the necessary environment and to handle all the recognizable parameters for it by far this program had the possibility to give us a good simulation but needed a lot of parameters to fulfill the desires solution and often the complexity leads to endless and usable results or to results by far different to the expected solution. As a result, they used software for simulating such neural networks caused a lot of trouble. The only problem was that you have to be very familiar with this software, have to buy the necessary libraries which are not in the basic package to exactly find the algorithms which are suitable to our solutions and problem. The algorithms were so complex, and we faced limitations in executing them easily.

After facing these problems with the aid of MATLAB we decided to use a new kind of software which was open source easily used by anybody and with their ability to adapt libraries which are free in the Internet. The topic of this software solution was using deep learning techniques in addition to software which are free and open source through the Internet to compare if all the calculations we made with the MATLAB software could be replicated and easily use deep learning techniques to find our solutions.

Because Deep learning is not our main topic, we use all the results and know-how for our problem.This leads us to also find another way to simulate exact the same things with a newer and more hopeful software solution using Jupyter notebook. It is web based, opensource programming environment with endless new libraries ready for complex calculations and simulations. One of its features is that we can use except of Python also R, C# and other programming languages to feed the code. We used it in the field of Neural Networks and especially for Artificial Neural Network (ANN). Processing like the human brain different task and problems leads us to a basis to develop a strategy and algorithm that can be used to model complex patterns and prediction of problems in any way. With this we developed an ANN corresponding to the same Data set as used prior in MATLAB and the results were more realistic and more configurable. Another possible approach would be to develop an algorithm which implements also parallel programming to have the best results quicker and more complex to the human actor.

5 Problem Definition

The findings require more efforts to design strategies that work more on the behavior. These strategies require assembling software and algorithm techniques in addition to academic professionals to work on finding more measurable results. We have to deal with very different parameters, and we must have sufficient Data to relate it to the new algorithms. So, there is a need for more intelligent systems to support different tasks. Although there are several types and techniques related to face the objectives and there is no clear-cut definition which one is now most suitable type and technique based on the required task.

Based on our preliminary results extracted from the different types of intelligent systems, the facts show that Neural Networks, Parallel Programming and Data mining methods can be used collaboratively for tasks such as modelling and prognosis that can help extract classifications and clustering tasks.

6. Future Work

A catalogue of known seismic events attributed to specific underground faults could be used as training data set in various AI systems. The problem is that such catalogues are short in size and difficult to prevent overtraining the various AI systems. Still, if some convergence is achieved, then alongside with proximity and parallel spatio-temporal clustering algorithms it might be possible to infer a solid conclusion on the allocation of particular earthquakes to a specific underground fault.

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Seismic Ontology Exploration via Deep Learning and Heterogeneous Parallel Algorithms

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1. INTRODUCTION

Seismic activity along Greek territory, has been a very interesting subject among dominant topics of the Greek science community due to the critical stead the Greek surface extends in reference to its tectonic position which for the most part is placed on the Eurasian plate with Crete's location in close proximity to both the Eurasian and African plates while both of those plates share common points with the Arabian plate, creating a three plate convergence in close proximity to Cyprus geographical location, further creating interesting seismically unpredictable high activity to the surrounding regions, including the Greek seismic belt.

2. MATERIALS AND METHODS

The basic source of seismic intelligence for this operation originates from the Hellenic Seismic Network. The Hellenic Seismic Network (HL) is operated by the Institute of Geodynamics of the National Observatory of Athens (NOA-IG). The service to monitor seismicity in Greece and the adjacent region has started back in 1893 with the first seismic network operating 5 stations. In 2000, a large upgrade towards digital monitoring with broadband stations was initiated. Today, the Hellenic Unified Seismic Network (HUSN), with NOA-IG as coordinator and the three University Seismic Networks (Athens, Thessaloniki and Patras), makes available at NOA-IG in near real time waveform data exchange with more than 150 stations. Further information is available at the institute website (GI-NOA, https://bbnet.gein.noa.gr/HL).

Available graphs, data matrices and observations from the website are utilized, aided by data science software, to further augment and amplify the possible usableness of the data received. Following systematic research, clarification and guided extraction of various interesting findings with multiple purposes (Pu et al., 2021; Shokouhi et al, 2021), like observing data of seismic nature along a variety of variables, like geolocations, intensity, time values, which would otherwise be almost impossible to observe and would require extended attention.

Along the significant observation operation, further actions are performed, using data processing tools, to create measurement relation and pattern recognition algorithms with the aid of Neural Networks for machine learning and parallel processing (Ting, 2011) for big data handling. a Deep Neural Network was trained and refined with pattern recognition and event prediction attributes on seismic data with magnitude greater than 4 Richter. The user maintains full control over his data choices depending on what must be achieved. The training algorithm (Chollet, et al. 2018; Chollet, 2021) consists of an input layer with 6 input neurons for the insertion of Year, Day, Month, Latitude, Longitude and depth. 6 layers with 100 neurons in each layer, and 1 output layer which is the value this system is trained according to. This value is the Magnitude. The training can take some time and it depends on the training and test error values, which must be low and similar in size. Due to the time needs of the system, the trained model is exported where it is separately saved for further use by the prediction algorithm. along with a user made matrix of custom seismic values the network was trained upon, and conduct custom predictions.

This whole concept was developed as an advisory tool for seismic data manipulation, grouping and pattern extracting (Tang, et al., 2014) in small targeted areas and has produce very interesting results for individual seismic regions, like a vertical seismic activity that has been observed in the past 10 years on the region between Syrna and Kandelioussa. This area's coordinates are Latitude: 36,4 and Longitude: 26,7 with the network achieving very low error rate, meaning there is a repeating pattern of seismic events concerning this specific area.

DATE	TIME (GMT)	LAT. (N)	LONG. (E)	DEPTH (km)	MAGNITUDE (Local)
1964 FEB 24	23 30 25.0	38.90	23.90	10	5.3
1964 APR 11	16 00 00.0	39.75	25.25	10	5.7
1964 APR 21	08 14 40.0	38.50	22.25	10	4.5
1964 APR 24	03 49 58.0	38.00	21.80	10	5.0
1964 APR 29	04 21 00.0	39.25	23.75	10	5.8
1964 APR 29	17 00 03.0	39.25	23.75	10	5.2
1964 APR 30	18 11 00.0	39.25	23.75	10	4.9
1964 MAY 2	23 24 00.0	39.25	23.75	10	4.2
1964 JUL 12	23 32 50.5	38.50	23.25	10	4.4
1964 JUL 17	02 34 28.0	38.00	23.50	150	5.8
1964 JUL 18	03 40 11.0	35.50	25.50	10	5.4
1964 AUG 30	15 52 36.0	37.25	21.50	10	3.9
1964 OCT 6	14 29 57.0	39.75	28.00	10	5.3
1964 OCT 6	14 31 22.0	39.75	28.00	10	7.0
1964 OCT 13	21 06 46.0	37.50	22.50	10	4.3
1964 OCT 16	11 22 04.0	38.50	22.25	10	4.7

Figure 1: Data available in Geo-dynamic Institute Website

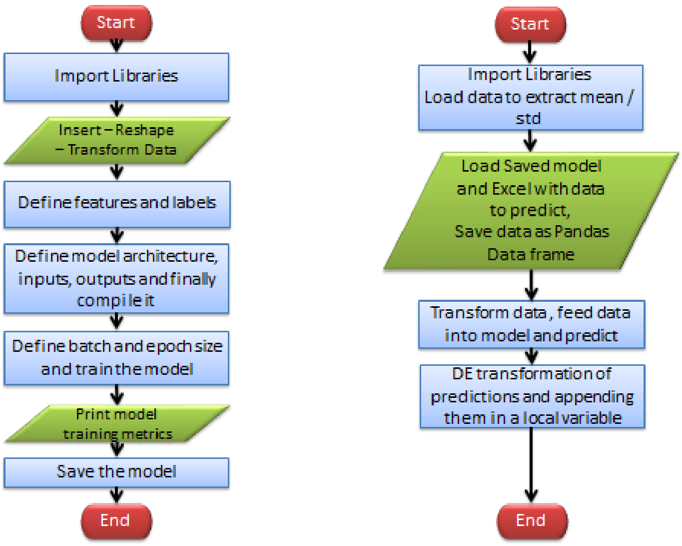

Figure 2: Flowchart of training the model (left) and testing the model (right)

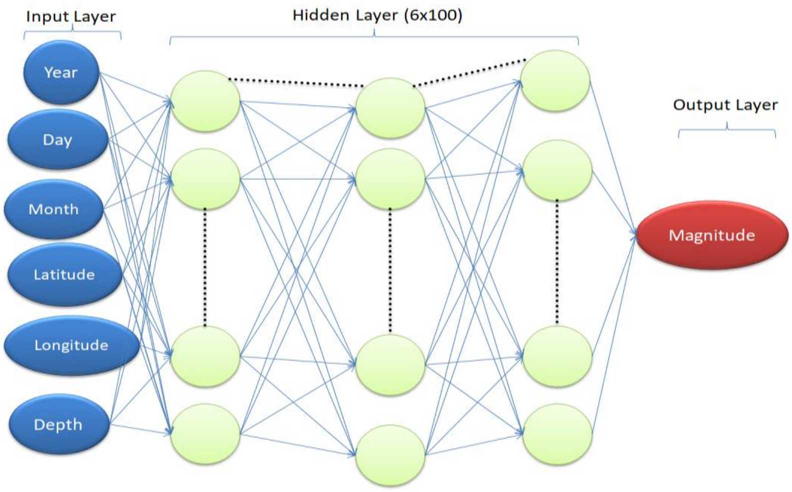

Figure 3: Shape of the model with input layer, hidden layer and output layer

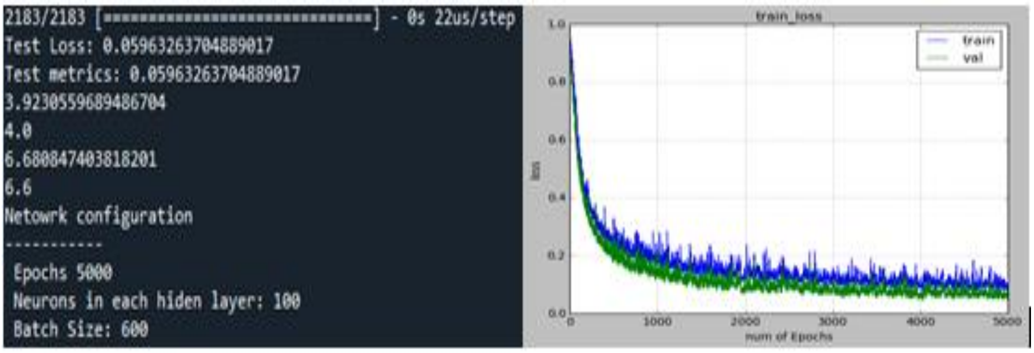

Figure 4: Training and testing values

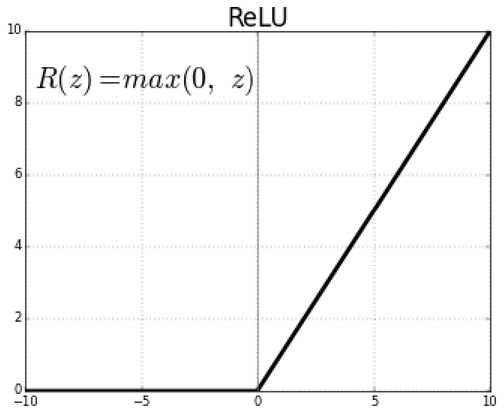

Figure 5: The rectified linear unit is the activation function in use

3. RESULTS AND DISCUSSION

Variable results are produced through this work ranging from visual data to mathematically trained artificial neural network models. The trained models perform improved pattern recognizing as the dataset range is getting more specified, which is to be expected, so it is recommended to either use large datasets and filter possibly indifferent data prior to processing or use smaller datasets. It is up to the user to conclude the research and calibrate the values. This work uses datasets estimated between 6000 and 340000 records in order to produce both small- and large-scale models. The data visualization always uses the maximum number of records. Through Open GL and R studio, data can be visualized in an interactive three-dimensional space with capabilities of further extraction and presentation of those values in a plethora of forms.

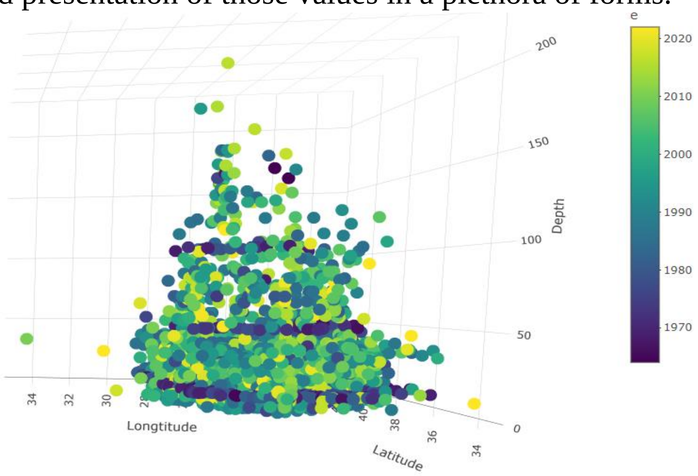

Figure 6: Seismic Data plotted according to longitude, latitude and focal depth, colored based on year of occurrence

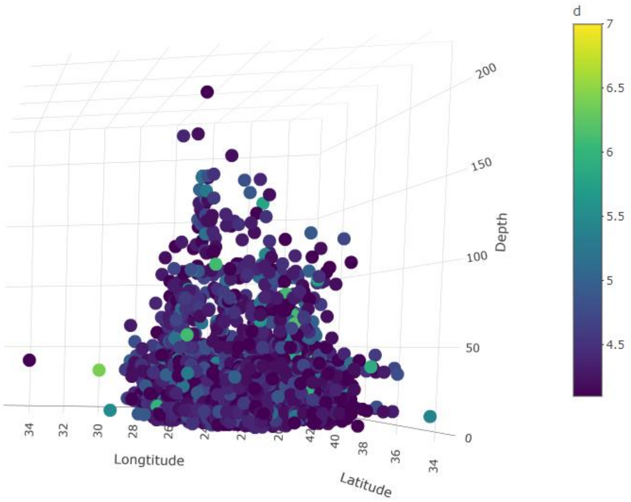

Figure 7: Seismic Data plotted according to longitude, latitude and focal depth, colored based on magnitude

4. CONCLUSIONS

Through this study, various tools are used according to mathematical models describing how a neural network model is designed and trained. For an optimal design, a good grasp of data form must be achieved so that the validity of the results can be roughly estimated before further calculations are processed.

The software libraries that are used are frequently enriched so it is of vital importance that the documentation is always revised for new capabilities that may provide the necessary tools depending on made study. Up to date hardware is also a plus, because the more data processed the better score models achieve. Year by year, earthquake data providing organisms provide rich and diverse data, which translates to more viewing angles for past and future research.

Future work shall aim at attempting various deep learning approaches on temporal modelling, spatial modelling, spatio-temporal modelling, along with magnitude estimation of forthcoming seismic events. The ultimate target remains the decoding and modelling of the seismic phenomenon of potentially distinct seismic areas.

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Custom-made 3d printed nozzles for Laser Wakefield Acceleration (LWFA) experiments in the Institute of Plasma Physics and Lasers (IPPL)

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1. ABSTRACT

3D printing or additive layer manufacturing refers to various techniques that have been rapidly developed since the ’80s. The field of their applications is wide because they present various advantages, as custom-made CAD drawings can be printed within a short time, while the cost of a printer for in-house production or of pieces from external collaborators is low (Sachs et al., 1992; Levy et al., 2003; Wong et al., 2012; Conner et al., 2014). In IPPL we are producing custom-made nozzles for LWFA experiments. The designs of the nozzles are sent to collaborators to test different printing technologies and qualities.

2. INTRODUCTION

Laser-driven electron acceleration is a fruitful field that attracts global research interest. Many groups are working on electron beam characteristics optimization as the applications are numerous (Malka et al., 2008). LWFA is the most widely used method for the acceleration of electrons up to the GeV level (Gonsalves et al., 2019). Experimentally an ultra-intense ($I>10^{18}$ W/cm^2), ultra-short (t~50 fs) laser pulse is focused on an under-dense target. The parameters that interplay and lead to the tunability of the acceleration are the laser pulse characteristics (e.g pulse duration, energy) and the gas density profile. As far as the gaseous targets, especially designed gas jets, gas cells, or capillaries are mainly used. In the target fabrication area, fast prototyping provides the ability to change targets according to experimental or numerical findings (Prencipe et al., 2017).

The experiments take place at IPPL, a research Centre of Hellenic Mediterranean University (HMU) using the laser ‘Zeus’ (Clark et al., 2021). ‘Zeus’ operates with a 10 Hz repetition rate and delivers pulses of 1.2 J maximum energy and 25 fs duration with a central wavelength at 805 nm. The laser is guided to the vacuum chamber and focuses on a focal spot of ~30 μm diameter, resulting in peak intensity > 10^{18} W/cm^2. The focus is on the top of a pulsed gas valve, where a nozzle is placed to form the gas density profile. Initially, we were using a commercial needle-like nozzle with 800 μm diameter, stuck on a base (figure 1 (a). The base is following the design of the top of the valve and is screwed on top of it with 4 equidistant screws. However, to achieve tunability over the energy and charge of the resulting electrons, different gas density profiles, thus nozzles must be studied. In this context, we used 3D printing to print nozzles. In figure 1 (a) the needle-like nozzle and the first successfully printed nozzle are presented, together with their resulting electron spectrums. In (b) it is shown that the needle-like nozzle produces a 50 MeV electron beam with a narrow energy spread, while the conical 3D printed nozzle, produces a wider and higher energy electron beam (Grigoriadis et al., 2022).

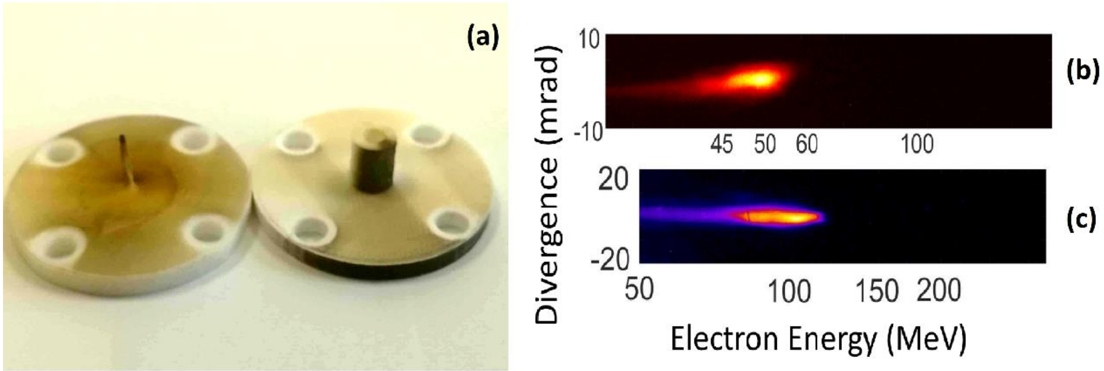

Figure 1:(a) The cylindrical commercial needle-like nozzle, 800 μm diameter at the exit, and the conical 3D printed nozzle, 3 mm diameter at the exit. (b) Typical experimental results of electron spectrum using the needle-like nozzle (50 MeV semi-monoenergetic). (c) Typical experimental spectrum using the conical 3D printed nozzle (~100 MeV, wider energy spectrum) (Grigoriadis et al., 2022).

3. METHODOLOGY

Using a computational fluid dynamics (CFD) code we first estimate the density profiles resulting from various nozzle designs. Selected designs are then 3D printed and used for LWFA experiments. This idea was first implemented by (Vargas et al., 2014; Döpp et al., 2016), and until then metal milling was used. The challenges that arise in LWFA experiments are numerous. Experiments take place under a high vacuum (~10^{-6} mbar) thus a piece must be vacuum compatible. Also, the smoothness of the piece must be very high, as any small unwanted remnant can affect the gas flow, or the flatness of the bottom base, which is necessary for the accurate fitting to the valve.

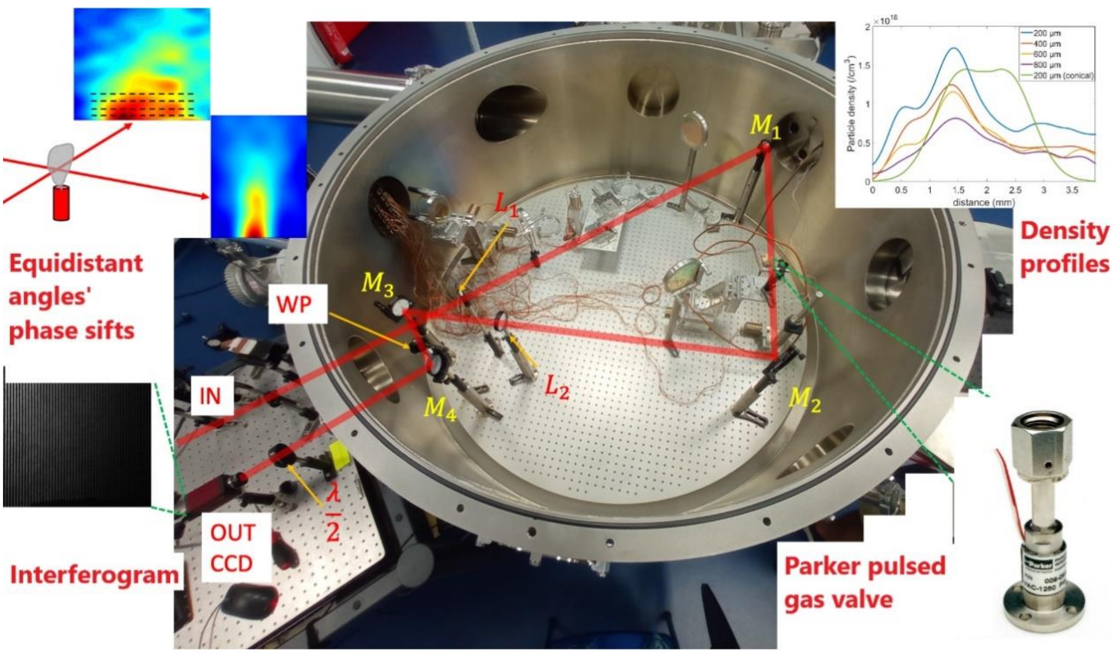

Figure 2: The experimental chamber where LWFA acceleration experiments take place under a vacuum. The interferometry set-up is illustrated (red line) and used for gas density measurements. When non-symmetric nozzles are screwed to the pulsed gas valve, a tomographic reconstruction technique must be applied to obtain gas density profiles. In this case, equidistant angles' interferograms must be analysed (Andrianaki et al., 2022)

The designs are continuously changing according to experimental expectations. Various nozzle and base thicknesses have been tested, along different conical geometries, as also non-symmetric nozzles (figure 3 (a)-(d)). When a new nozzle is designed, its performance must be characterized via the interferometry technique. As illustrated in figure 2, a Nomarski-type interferometer set-up is used (red beam in the chamber) and interferograms are recorded to obtain density profiles. To obtain density profiles for non-symmetric nozzles some equidistant angles' interferograms are necessary to apply a tomographic reconstruction algorithm (Andrianaki et al., 2022). In this case, to succeed accurate rotation of the nozzle the design of the base bottom surface had also to be altered (screw holes/30 degrees figure 3 (e) or channels of 30 degrees permitting the nozzle to move accordingly without moving the valve figure 3 (f)).

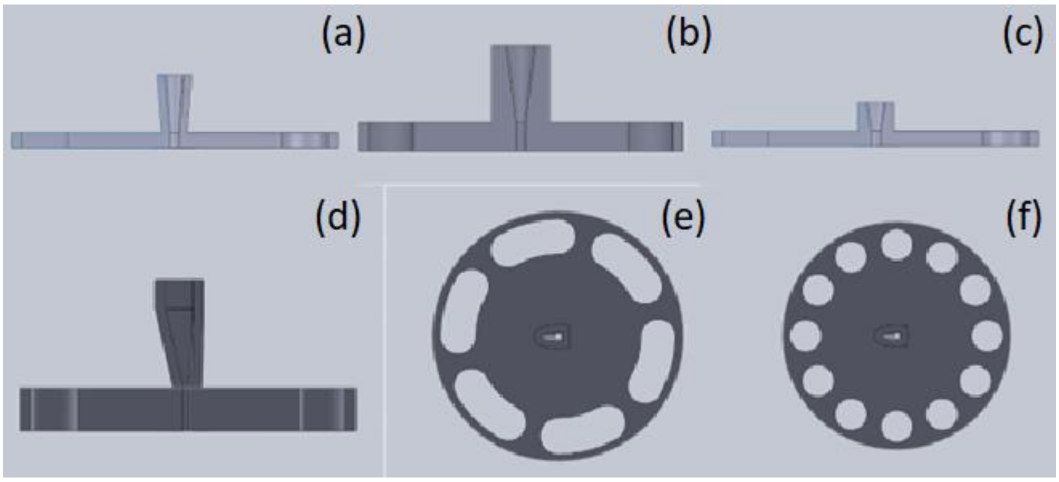

Figure 3: Designs for various nozzles and base geometries.

Fused Deposition Modelling (FDM), Stereolithography (SLA), and metal 3D printing techniques have been tested (Sachs et al., 1992; Levy et al., 2003; Wong et al., 2012; Conner et al., 2014).

In FDM, where a thermoplastic filament of diameter >1 mm passes through an extruder that is heated and melted, and is placed on the also heated, printer's bed. The extruder and the bed are both moving, and the resulting part quality depends on the printer's characteristics such as the printer's nozzle diameter, extruder and bed temperature, and layers' height. In our case, Prusa MK3 (Prusa Research, https://www.prusa3d.com) was available, with an 0.4 mm nozzle, a printing layer height of 0.1 mm, and the printing filament was PETG. We printed various conical geometries varying cone length, angle, base length, and cone thickness as can be seen in figure 3 (top). The nozzle in figure 1 (a) is the most utilized of them, as it has serviced thousands of full-power laser shots.

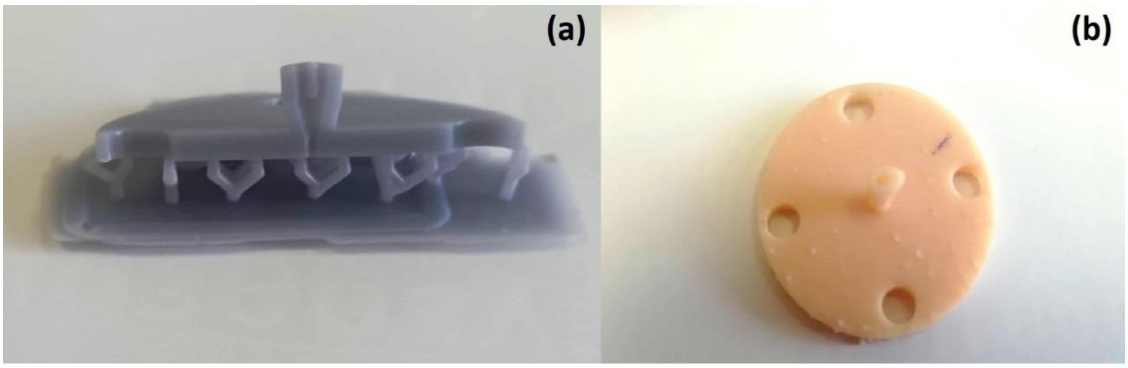

Figure 4:(a) SLA 3D printing using supportive material under an angle. After removing the supporting material the bottom base surface of the part was rough. (b) SLA 3d printing using supportive material inversing the part. The bottom base surface remains smooth.

To obtain finer details SLA technique was also tested. In this case, a tank full of liquid resin is locally illuminated with UV light and the resin is hardened. The printer's bed is gradually moving out of the resin, after the creation of each layer. Photon Mono X (Anycubic, https://www.anycubic.com) was available, printing using a UV LED light source (405 nm), with a layer height of 0.01-0.15 mm. The part after removal from the printing bed must be post-processed (e.g., remove support material, hardening). The printing was initially failing to create the smaller diameter of the hole at the base of the cone, which was designed to be 800 μm. The printing under an angle was first tested, using supports as is shown in figure 4 (a), which created the designed hole, but removing the supportive material was destroying the flatness of the bottom base area. Finally, the orientation of the printing part was inversed in Z-axis, and long supports were used, thus the nozzle exit remained unaffected, so the important surfaces of the part were flat and smooth, while the top part of the base was rough (figure 4 (b)).

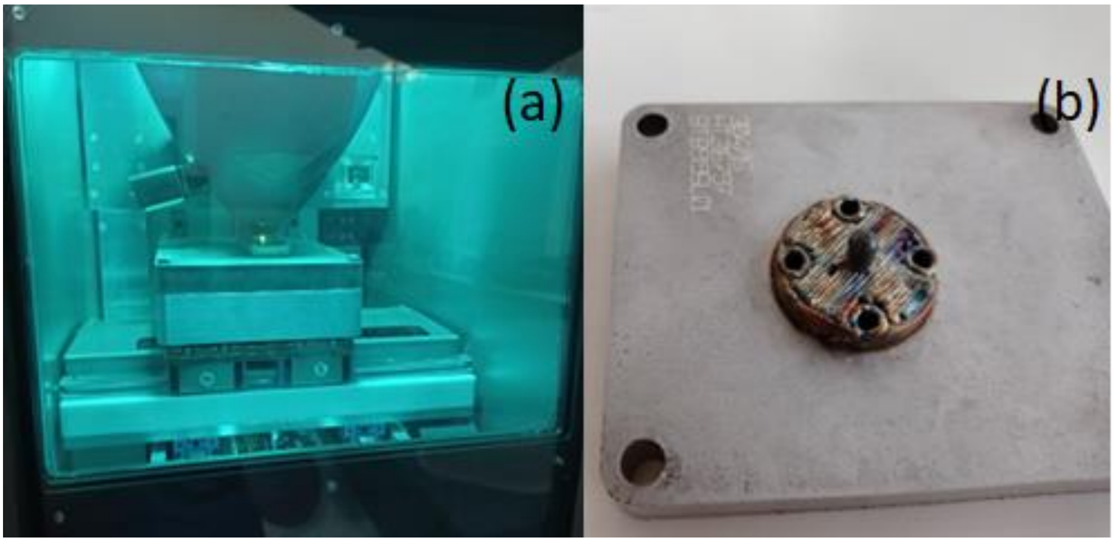

Figure 5: (a) MELTIO 450 printing procedure. Metallic nozzle welded on MELTIO 450 table. The warm metal collapsed without creating a hole

An unsuccessful test took also place using metal 3D printing, namely laser metal deposition with wire. In this case, a laser beam is melting a stainless-steel wire of 1 mm thickness, while the part is welded in special tables. The printing took place at the Laboratory of Computer-Assisted Machining (CAM) of the School of production and Engineering of the Technical University of Crete (TUC), using MELTIO 450 (Meltio, https://meltio3d.com). The simple conical design of figure 1(a) was tested. The size of the extruder's nozzle was too big to print it properly. As a result, the material was joined, without creating a whole at the centre. Another serious disadvantage was that the post-processing with a band saw, was laborious and imprecise, resulting in an un-homogenous base bottom surface.

4. CONCLUSION

LWFA is strongly affected by gas density profile. Based on CFD simulations we can test and characterize our nozzles (fast prototyping) in a quick and thrifty way. Various printing technologies were tested. SLA is delivering the most detailed parts among the others. Until now, our parts were delivered by various collaborators (HMU, TUC). This allowed us to obtain expertise and study the behaviour of each technology. The vacuum compatibility of the 3D-printed plastics permits their use in other items in the vacuum chamber too.

5. ACKNOWLEDGMENT

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Particle Acceleration and Radiation Emission Studies at IPPL

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1. INTRODUCTION

Laser-induced particle acceleration is a subject of great interest due to its numerous potential applications, among others in Inertial Fusion Energy (IFE) and in biomedical applications (i.e., hadron therapy). In this context, we present research activities using the ZEUS 45 TW femtosecond laser system, hosted at the Institute of Plasma Physics and Lasers (IPPL) [1] of the Hellenic Mediterranean University (HMU) research centre. This laser system delivers pulses with focused peak intensity greater than 10^{20} W/cm^2. Relativistic particle sources of electrons and protons generated by the interaction of ZEUS ultra-intense laser pulse with gaseous targets, are presented [2,3]. In addition, experimental results of the emitted Betatron-type coherent x-rays are presented [4]. These secondary sources have already been utilized in the irradiation of polymeric gel dosimeters and biological samples [5]. Our experimental results are supported by numerical Particle-In-Cell (PIC) simulations [6]. Furthermore, preliminary MagnetoHydroDynamic (MHD) [7] numerical results on the optical shaping of high-pressure gas-jet or plasma plume targets are presented [8-10]. The optical shaping is performed through colliding blast waves, generated by secondary nanosecond laser pulses. These steep gradient, shaped profiles are considered suitable candidates for particle acceleration experiments in the near-critical density regime [11].

2. RESULTS AND DISCUSSION

Figure 1 shows MHD simulation results of the temporal evolution of two colliding Blastwaves (BWs) counterpropagating inside the gas-jet density profile. The two laser pulses are parallel to each other, as seen in the inlet figure. The laser pulses are considered to be the result of beam-splitting of the 835mJ energy Nd:YAGG laser pulse into two laser pulses with half the initial energy each, and 6ns pulse duration.

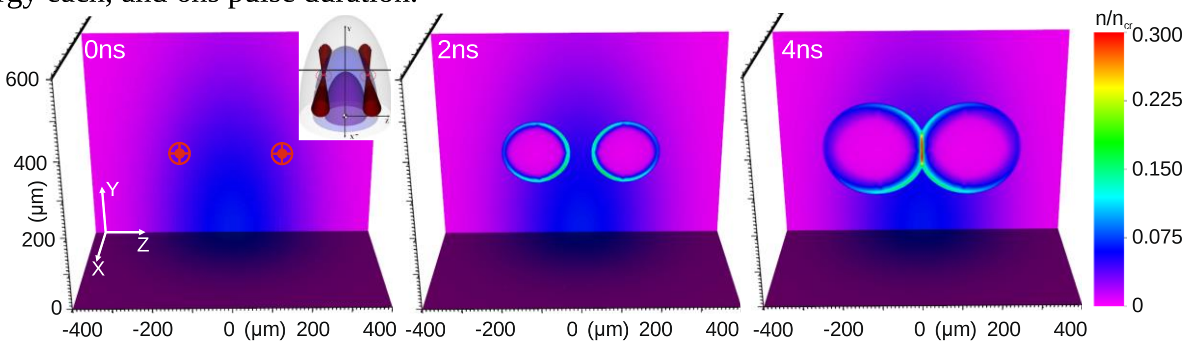

Figure 6: temporal evolution of the two colliding BWs generated by parallel laser pulses

The maximum compression of the density profile, that is that defined to be the ratio of the peak density over the initial, uncompressed density is C = 6.3.

Figure 2 shows the temporal evolution of two colliding BWs, generated by two laser pulses that intersect at a 60o angle, as seen in the inlet figure. The maximum compression of the gas-jet profile was C = 10.5.

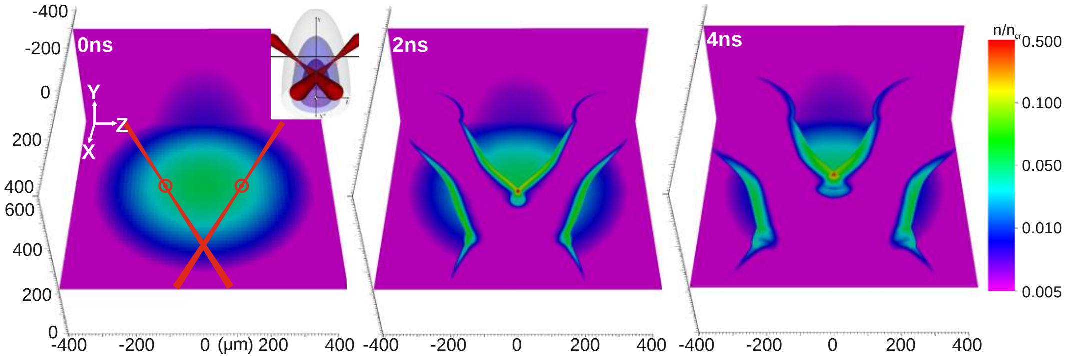

Figure 7 temporal evolution of the two colliding BWs generated by intersecting laser pulses

These compressed plasma slabs, typically are very short-lived, maintaining their compression for a few hundreds of ps. Synchronizing the main fs accelerating laser pulse with such a time window can be experimentally challenging. By setting two laser pulses intersecting at a 60° angle, sufficient compression was maintained for >2.5ns, resulting in a >10 times longer time window. This behavior is favorable for proton acceleration experiments due to the large, ns-scale time window, offered for synchronization with the main laser pulse under laboratory conditions.

These steep gradient, near-critical density gas target profiles can be used for ion acceleration experiments in the NCR regime. The NCR regime is considered when the target density is between 0.1 – 10 times the laser's wavelength λ critical density ncr. For λ = 800nm, ncr ~ 1021 electrons/cm3. PIC simulations of the interaction of ZEUS super-intense laser pulse with the compressed target profiles acquired by the MHD simulation were performed to study particle acceleration by Magnetic Vortex Acceleration mechanism (MVA) [13-16]. Figure 3 presents the PIC simulation results for the azimuthal magnetic field Bz, characteristic of the MVA mechanism and the proton density, given as ionized hydrogen density normalized to the ncr (nH+/ncr) at times t = 200, 250 and 300 fs of the simulation. The fs laser pulse penetrates the peak electron density of the target at t = 175 fs. The maximum Bz value is ~0.5 105 T at t = 200fs. The maximum value of the longitudinal, accelerating, electric-field along the X-axis Ex is ~ 8 1012 V/m. The accelerated proton bunch is highly collimated as seen in figure 3, with cut-off energies exceeding 15MeV.

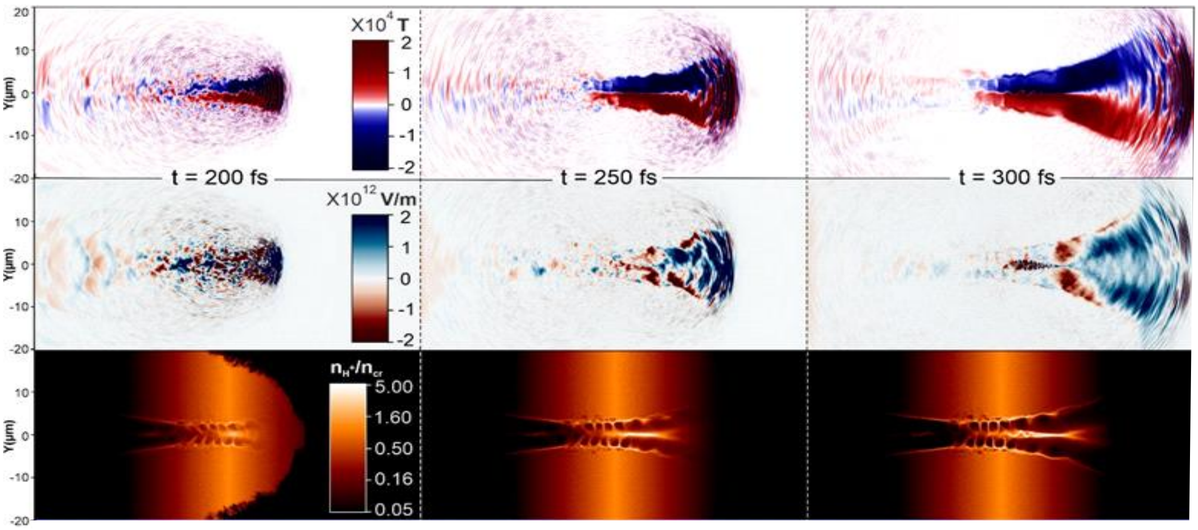

Figure 8: magnetic field B_z (top row), longtitudinal electric-field E_x (middle row) and proton density (bottom row) for 200, 250 and 300fs of the PIC simulation

Figure 4 shows the experimental results of Laser Wakefield Acceleration (LWFA) electron beams generated by the interaction of ZEUS 45TW laser pulse with under-dense gas target profiles, using a 0.8mm cylindrical nozzle and a 3.0mm diverging nozzle. Electron energy spectra were acquired using a 0.5T magnetic spectrometer along with a lanex screen. While the 3.0mm nozzle results in higher cut-off energy electron spectra, the 0.8mm nozzle delivers electron bunches of high reproducibility with quasi-monoenergetic characteristics.

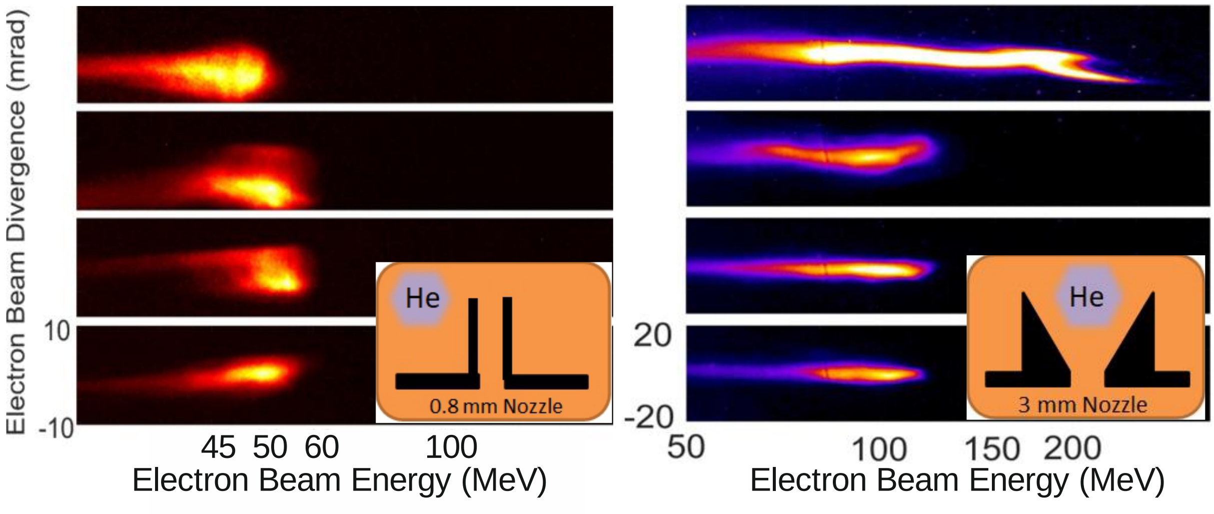

Figure 9: electron energy spectra using a 0.8mm cylindrical nozzle (left) and a 0.3mm divergent nozzle (right)

Figure 5 shows typical relativistic electron spectral images (left) and their corresponding Betatron-type x-ray emission (right) recorded simultaneously in single-shot interactions of the 25 fs laser pulses with He, N2, Ne, and Ar gas targets.

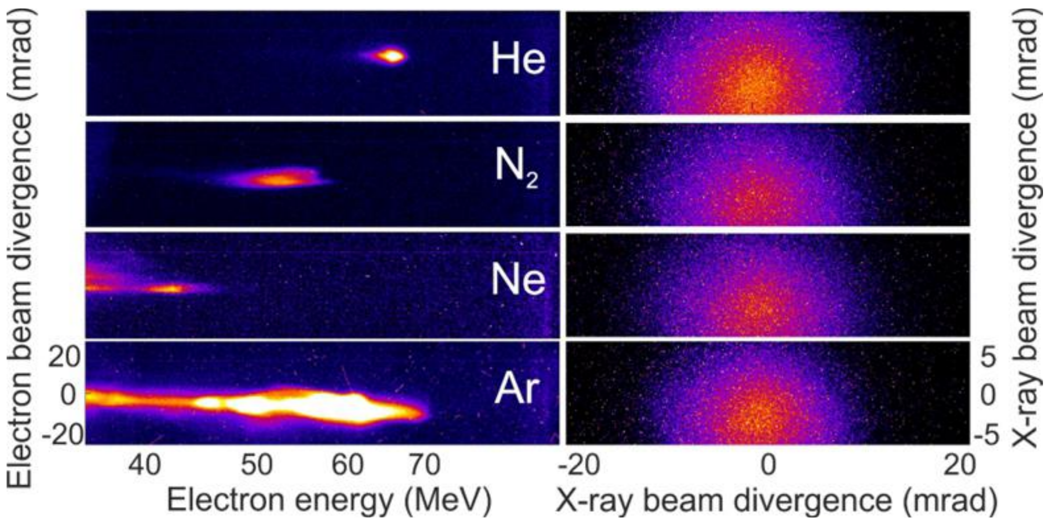

Figure 10: electron energy spectra (left) and corresponding betatron radiation emission (right)

3. CONCLUSIONS

Relativistic electron and Betatron-type x-rays secondary sources have already been developed and utilized in applications in IPPL of HMU. We further intend to implement an experimental set-up for the generation of high-energy protons and ions, based on the results of this numerical study. For these experiments, the high-density gas-jet target will be delivered by a Haskel air-driven hydrogen gas booster, able to support 1000 bar of backing pressure, along with a Clark Cooper Solenoid valve. A Q-smart 850 Nd:YAG laser will be used for the generation of the multiple BWs. The density profile characterization will be performed inside a vacuum test chamber of 60 cm diameter. This setup will be further installed in the main vacuum chamber of 1.5 m diameter where Zeus laser pulses will irradiate the near-critical density target. The fs 45TW laser pulse of Zeus will be focused using a 1μm focal length, a 30^o off-axis parabola, capable to focus to a 3 μm FWHM focal spot, with peak intensity greater than 10^{20} W/cm^2**.**

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DIGITAL SKILLS AND COLLABORATION WITH BUSINESSES IN EDUCATION WORKERS OF THE FUTURE

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1. SKILLS NEEDED FOR WORKERS OF THE FUTURE

The world has become more and more dynamic and changing. Not only changes in the industry but also different kinds of crises like COVID-19 influenced skills that are needed in the current world (Bremer & Maertens, 2021). Today's world is volatile, uncertain, complex, and ambiguous, so organizations and employees are interested in ways of developing skills in the VUCA environment (Horstmeyer, 2020). It is crucial to achieve a good job post in the labor market by employees, and build competitive advantages for companies. This is made possible by the skills that are needed now and in the future.

As researchers underlined "The challenge is the inclusion of future trends, specifically the ability to forecast new skills or combinations of existing skills" (Telukdarie et al., 2021). Therefore, this short paper is focused on skills that are necessary to develop among workers in the labor market today and in the future. Often there are called digital skills. There are two main trends in defining digital skills in the literature. The first is related to technical skills like operating a computer and browsing the internet (Bhandari et al., 2021). Other future technical essential skills identified by researchers (Arcelay et al., 2021, Akyazi et al., 2022) are following: digital literacy, machine learning, artificial intelligence, human-robot collaboration, continuous learning, virtual reality and augmented reality, cloud technologies, cybersecurity. The second trend is focused on social-oriented and non-technical skills like communication, critical thinking, or problem-solving skills (Etheridge et al., 2021).

This short paper aims to create a big picture of research about digital skills. Based on this big picture it is possible to identify which areas of research are explored. Moreover, it is possible to identify the main research gap and formulate recommendations for future theoretical as well as empirical research. Because of dynamic changes and the development of digital technology, digital skills have become an urgent topic. Society has to face new challenges, therefore the need to learn future skills is underlined by managers from businesses as well as researchers (Kotsiou et al., 2022).

2. METHOD

To achieve the aim of this short paper, a bibliometric literature review was conducted. The *Web of Science Core Collection* database was used and analyzed. In this source of research, only papers focused on DIGITAL SKILLS in the topic have been taken into account. Among the whole collection 18 134 positions were found as the result of the searching. Next, those 18 134 positions were selected using a year criterium. Only papers published between 2017 and 2022 (6 years) have been chosen in order to select the newest research. After this step 6 329 positions were removed from the database. Eventually, this bibliometric analysis was conducted using 11 805 the newest positions about digital skills from the last 6 years.

To prepare a visualization of the research about digital skills, bibliographic data with 11 805 positions were transferred from the *Web of Science Core Collection* to the *VOS Viewer Software*. They were implemented from reference manager files in RIS form. Co-occurrence as the type of analysis was used with the full counting method. The minimum number of occurrences of a keyword was the five. All keywords from the database were used in the analysis to provide a reliable picture.

3. BIG PICTURE OF DIGITAL SKILLS BASED ON BIBLIOMETRIC REVIEW

The expression "digital skills" was used to conduct bibliometric analyses of research papers. The result of the bibliometric analysis was presented in Figure 1.

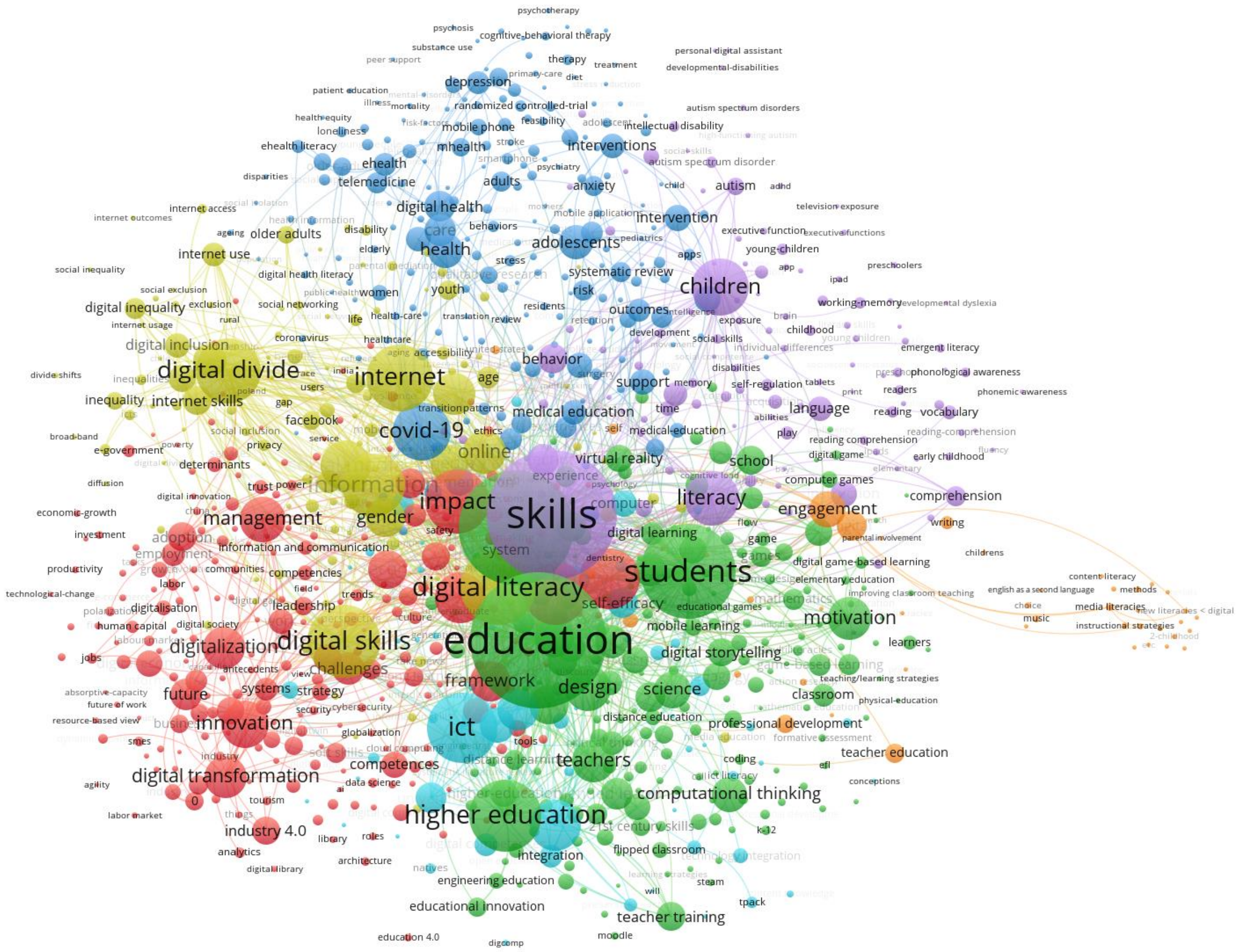

Figure 1. The bibliometric analysis of research papers focused on digital skills

Based on this big picture of the bibliometric analysis the following description can be shaped. The visualization was created based on the words "digital skills". Therefore, it is not surprising that skills are at the center place of visualization. It is visible also, that research in this area are focused on education, because the education has a huge role in developing skills.

The main research areas are gathered in a few groups with main topics. There are the following: education, higher education, and students (green area), engagement (orange area), children and literacy (violet area), health (blue area), digital divide, internet, digital skills, digital literacy (yellow area), management, innovation, future, industry 4.0, impact and digitalization (red area). Those fields were explored by researchers in the last six years.

Based on this bibliographic visualization it is possible to see also what kind of topics are missed. Digital skills are need not only among children or students. The majority of future digital skills are needed in companies and business environments. The first missing topic is related to learning among adults. Secondly, the most unexpected observation is that there is a research gap between digital skills and the business environment. On the Figure 1, it is visible that digital skills are developed through higher education, but there is a lack of business dimension.

The business managers` point of view, is clearly missing in the research. Keywords like: industry 4.0, competencies, productivity, human capital, labor market, and future of work - there are explored in a very small part. Those areas should be recommended for exploration in future research.

4. CONCLUSIONS

This short preliminary analysis showed that research about digital skills is strongly related to the education area. The majority of research dealt with students and higher education. Part of them were focused on children and the literacy. Internet and the digital divide were other big areas of research.

The main research gap which was discovered is related to lack of research located in a business environment. To prepare high-quality research which will be valuable for business, empirical research in the business environment are crucial. Therefore two main recommendations were formulated based on this analysis. There are following. Firstly, it is worth to realize research focused not only on children but also adults. Secondly, it is recommended to conduct empirical research in close collaboration with business. Those approaches create an opportunity to explore deeper the knowledge about digital skills among workers in a business environment.

This short paper has a lot of limitations. Firstly is it only the big picture of the digital skills. The visualization shows the map and main topics without particular and deep analyses. Secondly, only one source of the research was used. The sample consisted of 11 805 positions, however additional sources of the research could provide to another results. Thirdly, also other research gaps could be identified with using additional sources or wider database. However, this short paper is only the beginning part of the analysis of the digital skills needed for the workers of the future. Next, a deeper theoretical review should be conducted to explore this topic. The analysis focused on theoretical as well as empirical research to provide deeper knowledge about digital skills for future workers could be valuable, especially in the context of the continuous development of digital technology.

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SPECIFICS OF REMOTE TEACHING OF ENGINEERING GRAPHICS IN THE ENVIRONMENT OF SPECIALIZED ENGINEERING SOFTWARE FOR THE "MECHANICAL ENGINEERING" COURSE STUDENTS

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1. INTRODUCTION

The need to implement remote teaching due to the Covid pandemic has revealed a number of challenges related to the specifics of implementing online teaching of specialized technical courses. One of many such disciplines is engineering graphics. As for this discipline, students are expected to learn the general principles of design and representation of structures, as well as practically learn technical drawing of machines. This requires the development of spatial imagination, the acquisition of the ability to represent the basic parts of machinery on a technical drawing with appropriate measurements, learning the principles of creating complex drawings, including those defined by the relevant standards. The practical part of the subject is closely related to the performance of detailed drawings of parts based on complex drawings, taking into account dimensional tolerances, geometry and position, surface condition. The implementation of these tasks in the stationary mode of teaching requires the lecturer to comprehensively combine elements of classical lecture, practical and laboratory activities. For this, the effectiveness of teaching largely depends on the direct contact of the teacher with the student in real time (face to face). Unfortunately, this factor is eliminated in the mode of remote teaching implementation (Fig.1) in favor of the virtual connection of the "student-teacher" dual on or offline.

Figure 1. Elimination of real-time (face to face) contact of the "student-teacher" dual in the mode of remote teaching implementation

It is clear that in this case we can only hope to minimize the negative effects of this problem, especially in the teaching of strict engineering disciplines. One possible solution is to make comprehensive use of the capabilities of distance learning software and specialized engineering software during online lessons. Based on video conferencing software and the capabilities of specialized engineering software, combined with interactive lectures and video courses supported by teacher support and other resources (Fig.2), we create a virtual educational space that to some extent helps students reduce the lack of face-to-face contact.

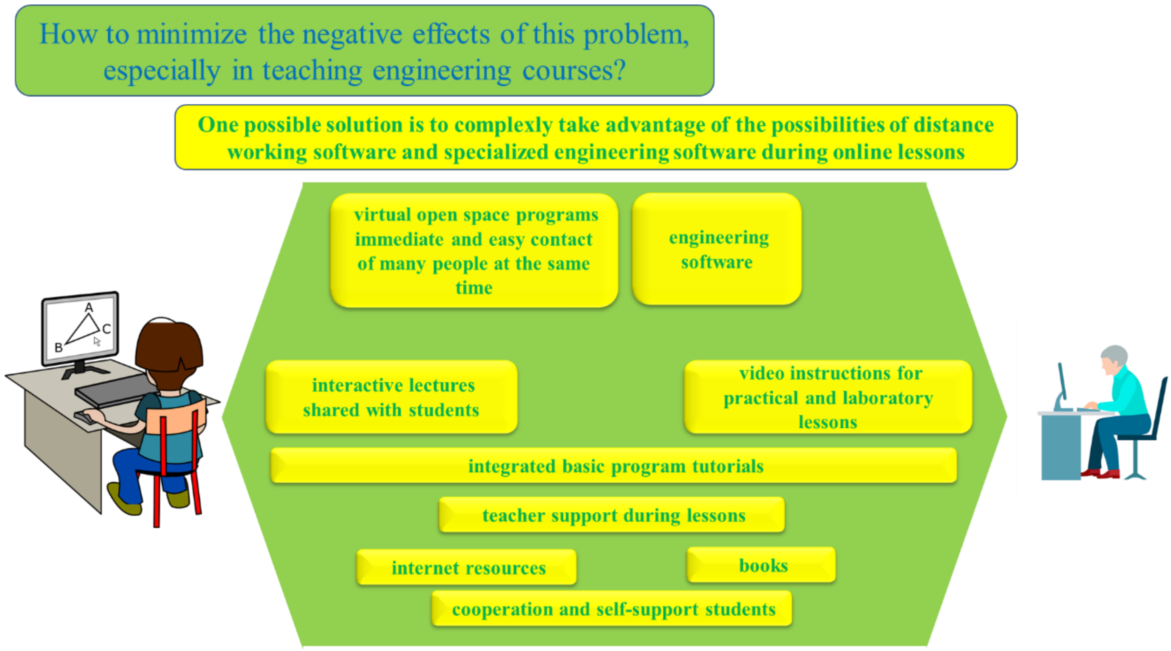

Figure 2. Concept of implementation of virtual educational space

Presentation of the functionalities of such a virtual educational space on the example of the implementation of the discipline of engineering graphics is the main objective of this article.

2. MATERIALS AND METHODS

The creation of a virtual educational space dedicated to the teaching of engineering disciplines is possible based on the hardware and software components of the individual workspace of both the teacher and the student (Fig.3)

Figure 3. Example of computer hardware and telecommunication software of the individual workspace in the virtual educational space

Since in the course of higher education, students perform a wide variety of tasks for this, each of them aims to use the most universally applicable computer equipment. As a general rule, there is a notebook with a webcam or a desktop computer with a media package in the form of a microphone, speakers and a webcam. For this we did not introduce any excessive requirements to the hardware except to provide the minimum requirements to provide security for the needs of both communication program and specialized engineering software. With regard to engineering software, an important factor in the selection was the requirement that the different versions of the software maintain a maximally identical user interface. This allows the connection of student computers of different power and productivity to work under identical conditions. Such considerations, among others, were the basis for the selection of a quality base software program from Autodesk AutoCad (Fig.4).

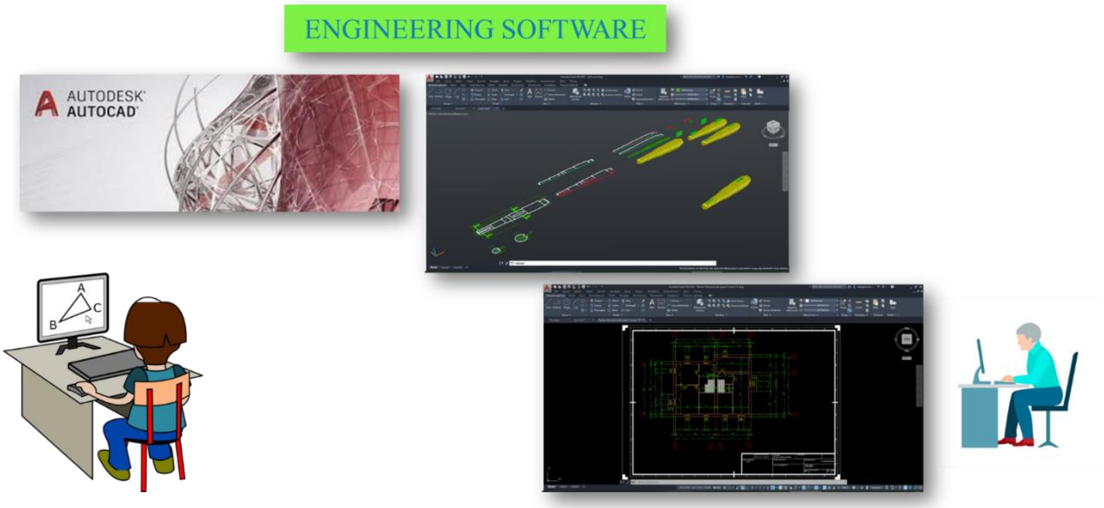

Figure 4. Examples of AutoCad use in mechanical engineering and civil engineering

The choice of this program is justified just by the presence of a free license for students; the ability to install the software on different operating systems; the identical user interface of new and older versions; the possibilities for use in different industries; version compatibility; and the absence of a physical license key. Another advantage in favor of such a choice is, of course, easy installation at home. With regard to the method of teaching engineering graphics distantly, it is necessary to note that the classic structure of the lesson must be modified due to the specifics of distance working and the technical possibilities of implementing the course. In general, the change concerns the structure of the course provided, the scheme of which is shown in Fig.5.

Figure 5. Example structure of a typical engineering graphics lesson provided online

Usually the lesson is separated into two parts: online and offline. Such a partition of the lesson, unfortunately, is a result of the limited possibilities of the students' equipment to work at the same time online with video, communication programs and just AutoCad software. Within the online part, the lecturer presents the students with the necessary theoretical information related to the general topic of the lesson using an interactive presentation in the environment of communication programs. The next stage of this part is to perform a sample task, this time in the environment of specialized engineering software with screen sharing and the necessary voice commentary. The conclusion of this part is the distribution of individual work between students for independent implementation. The second part of the activity takes place offline, primarily for each student. In this part, students perform an individual task in the AutoCad environment based on the provided presentation of interactive instructional videos using also integrated AutoCad tutorial. In case of any problems, the student turns to the lecturer and receives support for both technical and didactic problems. With the possibility of sharing the screen, the student can present his/her work-related problem and receive support in the form of suggestions for necessary actions or additional individual explanations related to the use of the environment and the performance of specific technical drawing elements.

3. RESULTS AND DISCUSSION

The online teaching engineering graphics, in addition to creating a creative educational virtual space, requires the student to be definitely more invested in self-study work. In turn, self-study work is not possible without access to relevant educational materials collected in a specific course. The optimal solution seems to be to provide students with access to all the materials discussed in the course, with the possibility of re-playing the moment the work is done. These objectives were the basis for the preparation of interactive presentations and instructional videos for each specific topic. Fig.6, 7 show fragments of these presentations and a frame from the instructional video.

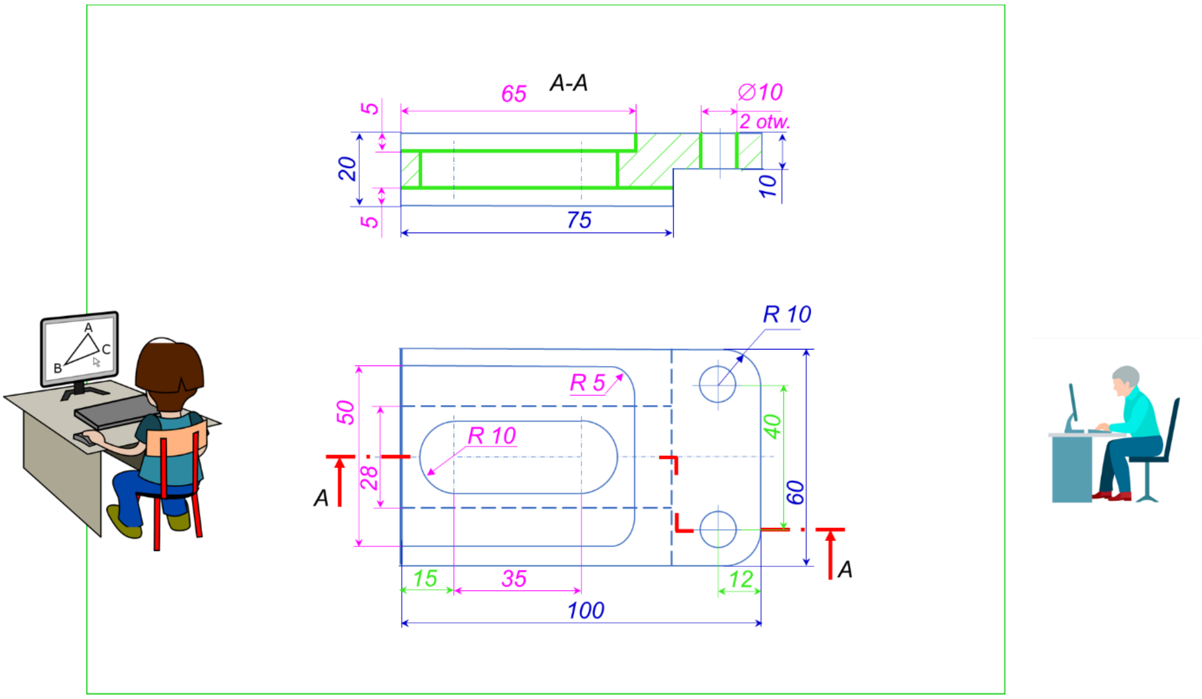

Figure 6. Example presentation slide of creating a cross-section and measuring a structural element

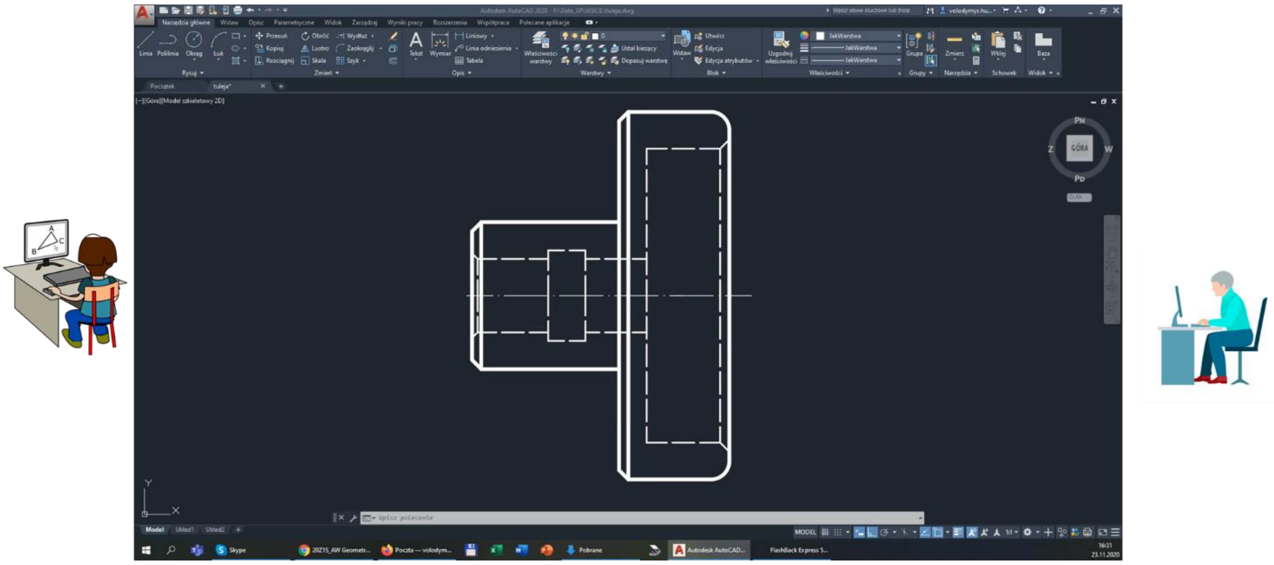

Figure 7. Example frame of an instructional video making a drawing of a half-view and half-section cross bushing

The characteristic aspect of this type of presentation is that the student actually has an interactive notebook of the topic. Having the possibility to change between the elements of the task at hand becomes an easy reminder of the procedure we discuss during the lesson. On the other hand, even without participating in the lesson, the student can always use the presentation to learn the necessary basics that make it easier for him to perform the task. An even greater role in this process is played by detailed instructional videos or where step by step presented typical solution of a problem from a given topic. It is worth noting that the greatest results can be achieved only when the student comprehensively uses both, since the presentation generally deals with the theoretical part of the problem, and the video more with the practical part. It is understood that an in-depth study of the topic requires the student to take a broader view and use other sources and literature, of course.

During the time of the usual online lessons, continuous students have the opportunity to get the support of the teacher implemented in different ways. The scheme for the implementation of communication between students and the teacher is shown in Fig.8.

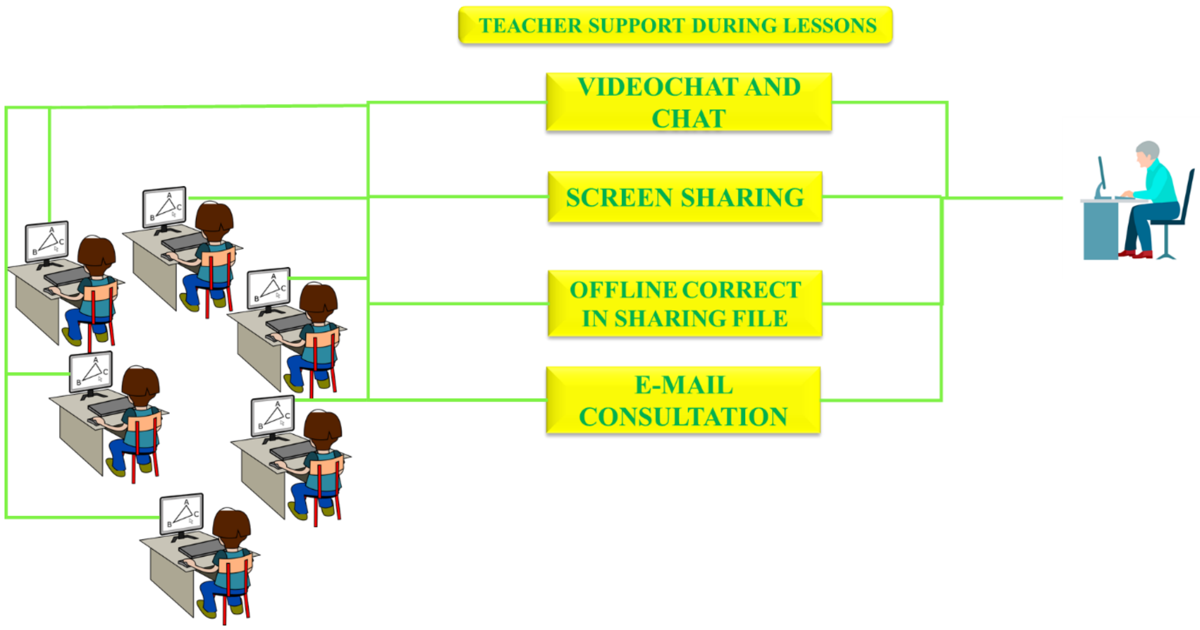

Figure 8. The scheme of implementation of "lecturer-student" support

The teacher's support is also separated conventionally into two parts. Direct active support is provided using video chat, chat, screen sharing. The other form of support is analysis and offline correction of shared files and consultation via email. Here it is important to note that these forms of support are realized in parallel, such can be distributed over time.

Evaluation of the completed work of students is carried out according to the scheme presented in Fig.9. The student completes the work within the time limit and through the appropriate communication program submits the original file for evaluation. Evaluations, comments, applied corrections in the original files are seen through these programs, and all doubts are clarified during online or offline consultation.

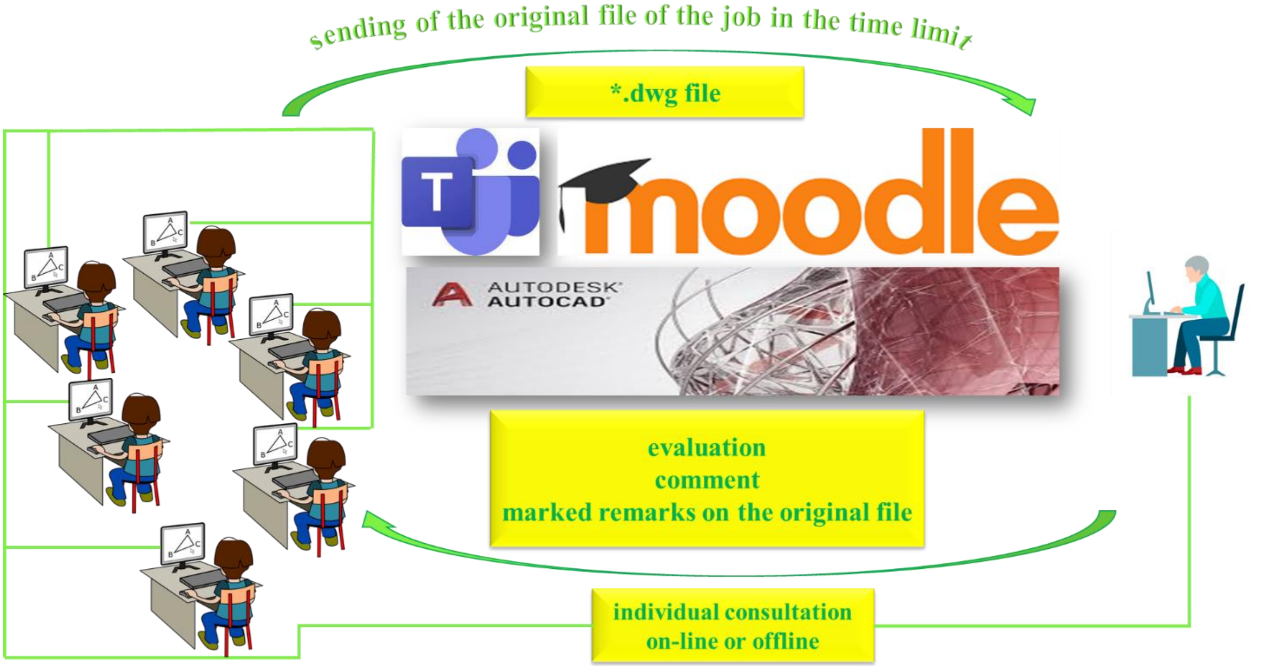

Figure 9. General scheme for evaluating student work

Depending on the communication program used, the view of the completed work for the student and lecturer may differ marginally (Fig.10). This does not have a major impact on the evaluation of the work because each participant in the process works in an identical environment of AutoCad engineering software and the mentioned programs are used only to transfer files.

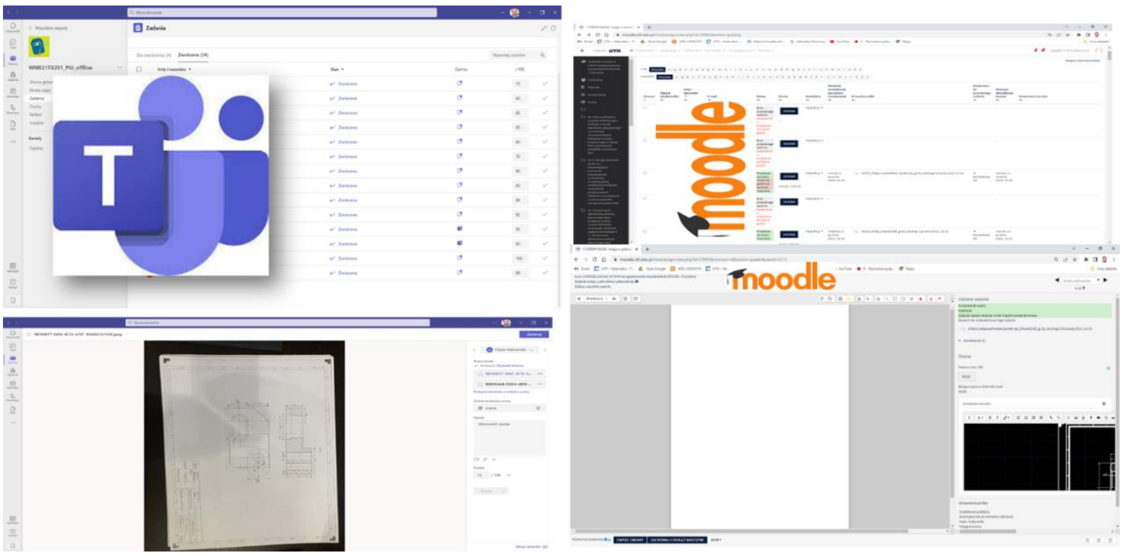

Figure 10. The image of a window with completed assignments in Microsoft Teams and Moodle environments)

Such an organization of the implementation of distance learning significantly improves the work, ignoring the fact that we still have no face-to-face contact. Also, the solution used does not eliminate the problems associated with the freezing of computers, the problem of connectivity associated with the low speed of the Internet or the necessity to perform part of the work in offline mode. Therefore, it is perspective to further develop the use of virtual machines and virtual laboratories in the teaching process. From the user's perspective, the use of a virtual laboratory increases productivity because there is no need to install specialized software directly on the user's computer. The personal computer is used only in the quality of a terminal for access to an external virtual machine, which allows you to work with software that requires a physical license key. Another benefit of such a solution is the ability of the teacher to control the performance of the student's work in real time. Thanks to the possibilities of the virtual machine, students can work in the same environment as operational as well as software regardless of the operating systems installed on their computers (Fig.11)

Figure 11. Example of starting different operating systems and AutoCAD software on a virtual machine

4. CONCLUSION

Summarizing the discussed information, we can conclude that at the present time, the current hardware and software infrastructure makes it possible to carry out distance learning of specialized engineering disciplines. The virtual educational space created on their basis allows the realization of a possible virtual contact between students and lecturers.

Complex use of appropriate communication and specialized programs allows realizing full control of the teaching process, archive the work of students in one place, write allow individual self-education of students.

The still remaining technical difficulties of the possible future can be eliminated by betting on the development of virtual laboratories and the extended use of student access to virtual machines.

WRITING AND SHARING PERSONAL STORIES AS AN ENGAGING TOOL FOR L2 PRACTICE AND LIFE-SKILLS DEVELOPMENT

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1. INTRODUCTION

The aim of this paper is to present a European funded Erasmus+ KA2 Project called *#shiftingwalls: European History through the eyes of the young* 7: the rationale behind the project, the goals, the materials and the work put together over the last three years by a multidisciplinary team made of professionals from different fields of expertise coming from universities, non-profit associations, educational foundations and schools from different European countries (Germany, Greece, Bulgaria, Spain and Lithuania).

This thought-provoking interdisciplinary project is about creating photo-stories (a short text accompanied by an illustrative image) which are later on published on Instagram -the most popular social network among youngsters- so that they can be shared all around the globe, giving participants the opportunity to work autonomously and in teams and also across national borders and cultures, creating contacts abroad and therefore triggering their motivation and engagement in a real and authentic communicative context [8].

These stories can be written in the students´ mother tongue, their co-official language or second language and/ or in the foreign language they are learning and this motivating and innovative project can be implemented in many subjects such as History, Art, Philosophy, Economics, Ethics, Social Science, Photography, Design, Religion, etc., but it is particularly stimulating and engaging for language learning as participating students practice the language in a real and authentic context which is also part of their everyday needs.

Despite practicing creative writing and understanding history from a more personal point of view are the main original goals, the project has a big potential as it goes further beyond by working with

- Multiple intelligences
- 21st Century Skills: the 4 C´s: Critical Thinking, Creativity, Communication, Collaboration
- Skills for life or soft skills: autonomy, time management, sense of initiative and entrepreneurship, sense of responsibility, team work, social and civic competences, imagination, personal development, decision making, reflective skills, cultural awareness, problem-solving, constructive criticism, assertiveness, emotional development, social responsibilities, emotional intelligence, empowerment, learning to learn, digital learning, independent learning, autonomous learning, curiosity learning, among others.
- 4 C´s of motivation: context, choice, collaboration and challenge.
- Learning to learn: engaging students in their own learning experience so as to achieve positive learning outcomes.
- Life-long learning

[7] KA2 EU Project #Shiftingwalls: European History through the eyes of the Young (http://shiftingwalls.eu/. VG-IN.BE-19-28-059960. Call 2019 Round 1 JA2- Cooperation for Innovation and the Exchange of Good Practices”.
[8] A one-minute promo video of the project is available at https://youtu.be/_349KlOFGD0

Fig. 1. Key words from the project

Although all the above mentioned skills and competences are developed through the participation in the project, we can summarize the project goals in the following three: (i) help students to combine their interest in communicating through social media with creativity, literacy, digital competencies, 21st Century Skills and use of foreign languages through creative writing in an L2, (ii) enhance the ability of young European students to apply creative thinking, curiosity and enquiry, social and communications skills, and achieve a positive change through innovative approaches to teaching, and (iii) ultimately promote language learning together with linguistic and cultural diversity

All in all, creating a short photo-story seems to be something simple and easy to do, but on the other hand, the project has shown to be a very powerful and beneficial one as it implies a successful and motivating way to involve students over the whole process as it makes them reflect on their learning, be involved in a very active, personal and creative way, thus making it a meaningful learning experience with very positive learning outcomes

2. MATERIALS AND METHODS

The project team has created a set of ready-to-use materials (in text and video format) for teachers and students (lesson plans, video and written tutorials, real examples of the project implementation, etc.) which are available in 6 EU languages for free in the project website www.shiftingwalls.eu.

These project materials have already been piloted by teachers and students from different EU countries and the project has been widely disseminated though workshops, multiplier events and international conferences around Europe, all in all proving that it is a very successful and sustainable project which can be very easily implemented and ensures a positive learning experience (both for teachers and students) and therefore positive learning outcomes, as results from anonymous evaluation questionnaires carried out over the last three years show.

The project can be carried out both face-to-face, blended and fully online, as proved by a group of students who successfully worked autonomously with the project materials in April 2020 during lockdown and also by the Moodle course being created for participating students in 2022. Moreover, it can be implemented in primary, secondary, tertiary and adult education, both in the public and private sector and within any educational program or situation due to versatile, flexible and multidimensional approach.

The *shiftingwalls* project was first piloted in Spain in the academic year 2019-2020 with a group of 1st year university students of English as an L2 and it has been successfully implemented since then in other subjects and with other university groups and secondary schools in Europe and the

USA. Moreover, it has been awarded twice as an Excellence Innovation Project by the Vice-rectorate of Innovation at UVa (2020-21 and 2021-22), it has been recognized twice as one of the best projects at UVa by the Chair of Knowledge and Innovation *Caja Rural de Soria* and has been recognized as an official innovative educational module that any UVa student can take in order to get ECTs credits.

The support from the European Commission, together with all the recognitions and awards mentioned before, prove that the project has a lot of potential from an educational perspective and it has proved to be a very sustainable one, due to its simplicity, interdisciplinary nature and most important, motivational and engaging aspect for youngsters, who are the main target the project is aimed to.

Although history was the starting point from the project and many photo-stories have been created in different languages by European students9, we have exploited the project further and have used the photo-story format with other topics, such as the COVID 19 Pandemic and a tool to fight against women´s violence. Thus, the Excellence Innovation Project "My COVID Story: a Journey Through the Eyes of the Young"10 , the International Contest "#25N against male violence" and the International Travelling Exhibition (also available online[11]) "Look at Us, Listen to Us. #25N: Multilingual audio-photo stories against gender-based violence"12 have been developed over the last three years.

Fig. 2. Instagram photo-story about Brexit. "Broken Hearts" by Clara Prada, available at https://www.instagram.com/p/CHTJ9HPgq0e/ (Spain 2020)

[9] The photo-stories created are available at Shiftingwalls Instagram account at #shiftingwalls_eu
[10] The photo-stories created are available at My COVID Story Instagram account at #my.covid.story.uva
11 Online International Exhibition:
English version: https://www.youtube.com/watch?v=LOpkX7S0HDo&t=9s ; Spanish version: https://www.youtube.com/watch?v=c__SNWuf4WA&t=1049s
[12] The photo-stories created for the International Contest and Travelling Exhibition are available at #25n_photo_stories Instagram account.

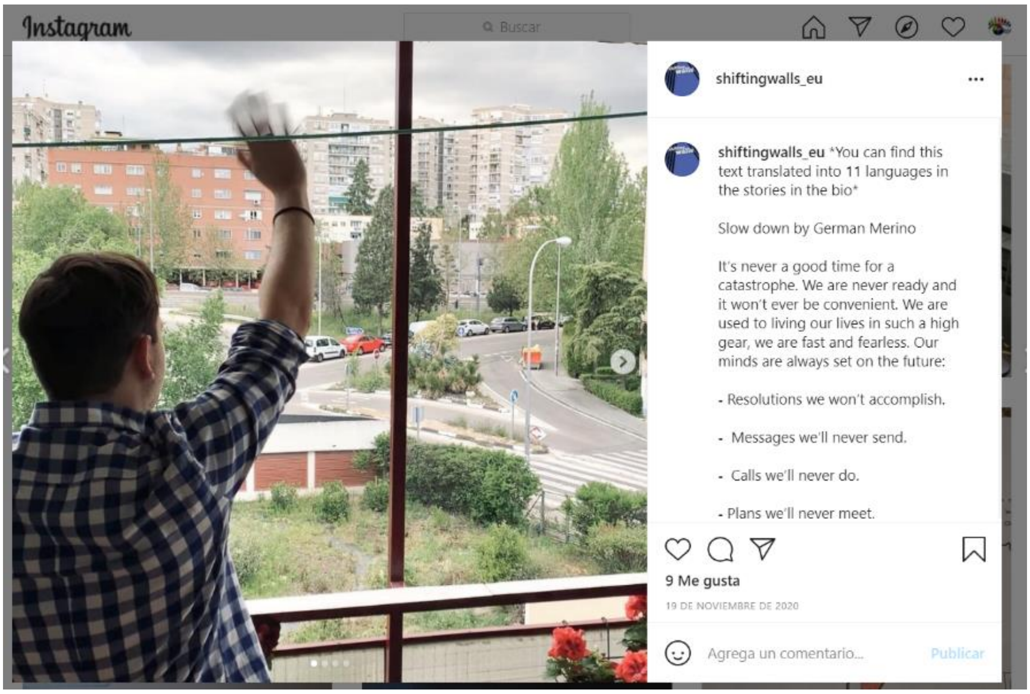

Fig. 3. Instagram photo-story about My COVID Story. "Slow Down" by Germán Merino 13 available at https://www.instagram.com/p/CHxN1ElAOt9/ (Spain, 2020)

Fig. 4. #25N International contest, travelling exhibition and example of one of the stories created (2020-21)

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[13] This photo-story has been translated into 10 languages and it is very representative as the student has also created (i) a portfolio/learning diary describing the whole process from the beginning to the end (https://docs.google.com/document/d/19t1MX90ZMaXZg0hcVWO2MA4TszuDnS-Dpc6D2AXCN3s/edit) and (ii) a video tutorial where he describes his work and experience while working on the project (https://www.youtube.com/watch?v=zlVcKFlvBAE&feature=youtu.be), being both documents a very powerful material for prospective participants as it explains the whole process step by step and from a student´s perspective.

	My transition gave me confidence Connecting with others, connecting with yourself Opening your mind, overcome obstacles, accepting others Now, knowing nature Friendship+ family= fears out Imagination, identity Day after day Emotions, empathy Nonsenses, the noise of our brain Change, challenge, come what may Enthusiasm, energy, equality

Fig. 5. Photo-story created by teachers in a Workshop (Spain, June 2022)

3. RESULTS AND DISCUSSION

Throughout the last three years, we have worked hard on the project materials which have been piloted in several EU countries and have gone through a continuous revision process after considering the feedback and suggestions received from experts, teachers but specially from all the European students participating in the project.

Results obtained from anonymous questionnaires have proved that this project is very powerful and is tailor-made to the situation youngsters are facing nowadays as not only does it provide a space for learning and practising several skills and competences in an authentic and motivating context, but also, it offers them a space to open their hearts, share their feelings with others and listen to other stories, which has also a very powerful and conforting healing effect.

Some results from the evaluation questionnaires are highlighted below

- It combines creativity, technology, creative writing and critical thinking.
- I think it's a pretty nice and educational project, as it can help you learn more about any topic.
- It is really different from what we are used to do, since most of us have never done a photo-story. It helps the students to think out of the box and try something new

Fig. 5: Students comments about the project (2020)

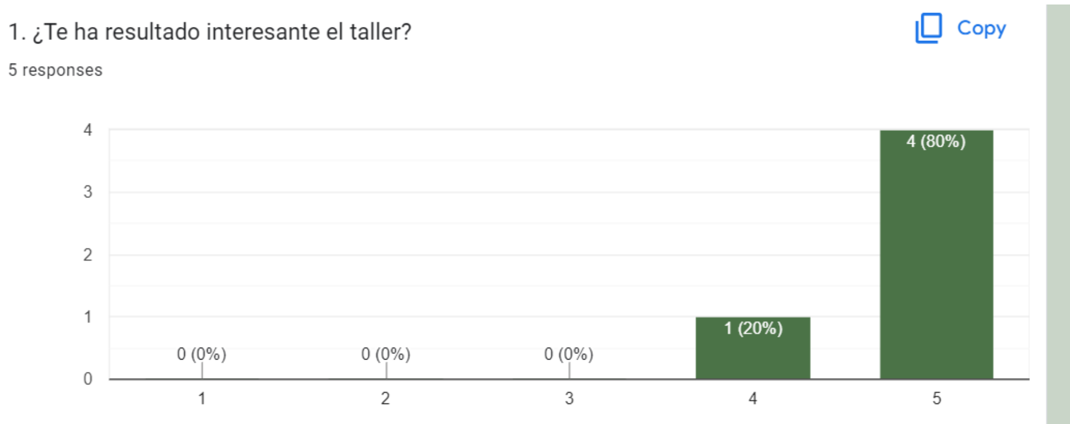

Fig.6: Teachers´ opinions about the project (Workshop June 2022)

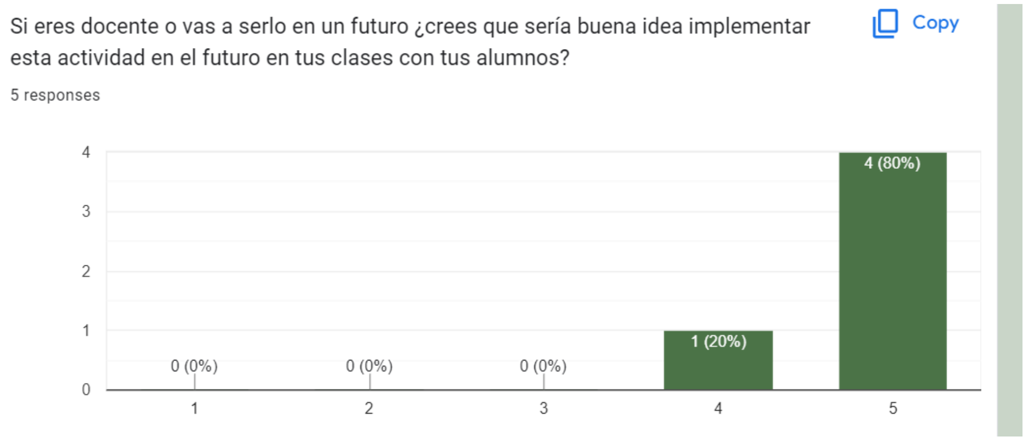

Fig. 7: teacher´s interest in implementing the project with their students

4. CONCLUSION

After evaluating all the hard work over the last three years, we are proud to see the positive results obtained until now. The Project has by far exceeded our expectations in terms of the number and variety of people who have shared their stories, on the one hand, and the variety of countries and diversity of cultures involved on the other, which has given the project a very special multicultural and multilingual approach.

Moreover, working with an interdisciplinary and international team and implementing feedback received from experts and especially teachers and students participating in the project, has allowed us to play with a very colourful variety of ideas and points of view, has favoured a very interesting and fruitful debate and reflection, has promoted collaboration and learning among team members and has had a very enriching effect on the project development overall.

The feedback received from the different project activities (workshops, multiplier events, with teachers and students, international conferences worldwide) not only has allowed us to improve the project materials, but has also provided us with very useful and thought-provoking ideas on how to exploit it further and make it sustainable for the future.

Dissemination is also a big success as the Project has been widely disseminated through articles written in specialised journals and conference proceedings, international conferences, workshops and multiplier events with European teachers, research projects on the topic, news published on printed and online newspapers, radio and TV, websites and blogs, not to mention the big impact through the Social Networks (Instagram, Facebook and Twitter)14.

All in all, we can claim that working with creative and personal ideas, playing with the language, exploring creative photography and using social networks to share your word are just perfect ingredients to engage students and build the motivation needed to learn and grow nowadays, a big challenge all educators are always working towards.

5. ACKNOWLEDGEMENTS

To the students for their enthusiasm while working in the project in such a creative way, to the teachers participating in the workshops and multiplier events for the positive way they embraced the project and to the sponsors, especially the EACEA (The European Education and Culture Executive Agency) for funding this KA2 project and the Chair of Knowledge and Innovation *Caja*

[14] Detailed information can be found at the Dissemination document available at https://tinyurl.com/2c2et82w

Rural de Soria, for their continuous and unconditional support on the different activities organized over this time.

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INTENSIVE DOCTORAL INTERNSHIP PROGRAM WITH STEM COMPONENTS

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1. INTRODUCTION

The program Erasmus plus is quite beneficial due to the opportunities given to PhD students to work and/or study abroad up to 12 month during the period of the dissertation implementation. The participation in international internship could also give the PhD students the option to have access to equipment and resources which the home university does not possess. Therefore, this kind of mobility could increase a lot the professional and personal opportunities of the PhD students and give them significant innovative advantages, https://erasmus-plus.ec.europa.eu/.

Besides, the University of Ruse in Bulgaria is well-known for its established traditions in terms of ensuring the quality of education and training in doctoral programs. The “Quality strategy” of the University is described in the main document, necessary for the national Accreditation. The following main objective of the quality management system of the University of Ruse is defined: realizing and maintaining high quality of education. The system is aimed at Bachelor, Master and PhD students, who are provided with educational, scientific and project services, https://www.uni-ruse.bg/en/education/phd.

2. PREREQUISITES FOR INITIATING INTENSIVE DOCTORAL INTERNSHIP

The Department of “Machine Science, Machine elements, Engineering Graphics and Physics” at the Transport Faculty at the University of Ruse has successfully supervised doctoral students for more than 45 years. And at the moment, accreditation is available for the scientific area “Machine Science and Machine Elements”.

An example for qualified supervision of PhD students is the annual implementation of the course "Automated Design Systems", aimed at improving the practical skills in working with SolidWork, CATIA and AutoCAD at the Department of “Machine Science, Machine elements, Engineering Graphics and Physics” at the Transport Faculty at the University of Ruse.

This course is an obligatory component of the Individual Plans of the PhD students at the same Department. The contributions and results of this very important activity have been analysed in details in (Dimitrov, 2018).

Figure 1. Pictures from the Summer International Internship during the period from 2015 to 2020

During the summer of 2015, the same department initiated and carried out the first international summer internship.

Practical training was delivered in English language by representatives of the department mentioned and by distinguished lecturers from other departments and faculties. The Faculty and Rector's management, colleagues from international office at the University of Ruse supported in a significant way the implementation of this summer internship, https://erasmus.uni-ruse.bg/en/?cmd=cmsPage&pid=39.

The activities of the University of Ruse to create and disseminate knowledge and ensure innovation and scientific research are the reasons for continuing the good practice of the International Summer Internship and creating an Intensive Doctoral Internship Program, in English language.

The International Doctoral Internship Program is open to PhD students from all European universities and it aims to support the collaboration of PhD students on scientific challenges. Another main objective of the International Doctoral Internship Program is to improve and upgrade doctoral students' practical skills and support their scientific research.

3. METHODS

The methodology of the research presented is based upon the academic experience of the authors' team in the area of using innovative training technologies for supervising PhD students. Various possibilities for improving the educational component in the training of doctoral students, mainly in the field of engineering sciences have been considered.

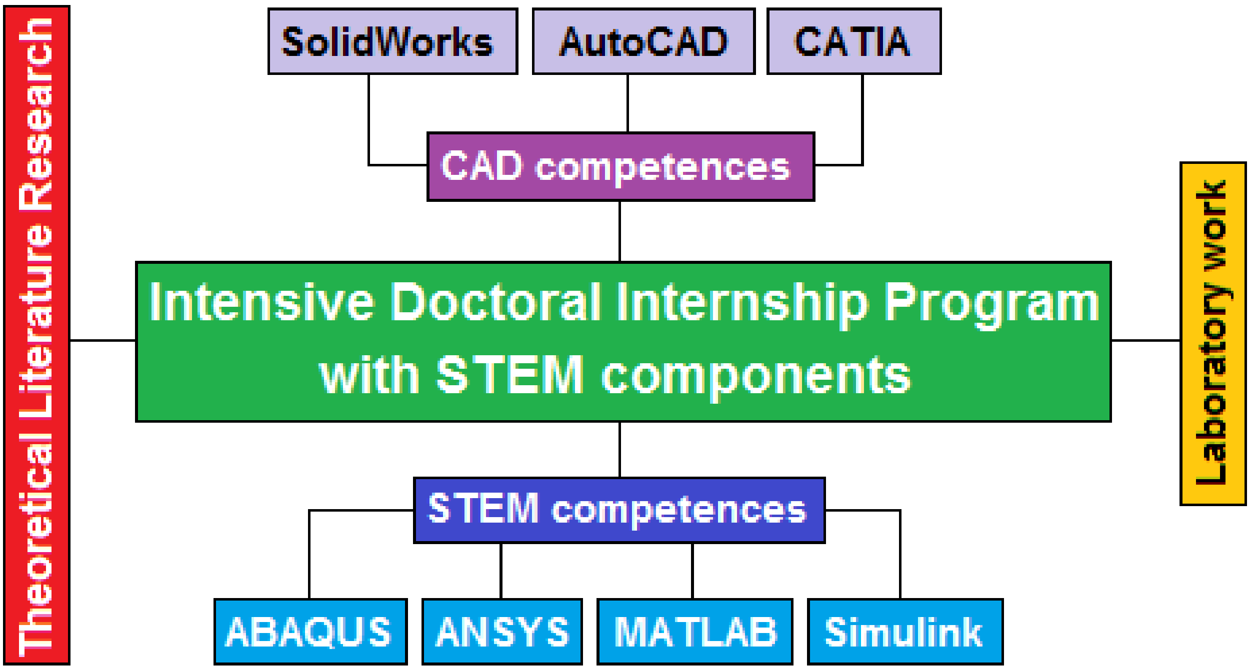

Figure 2. Practical courses and subjects of the Intensive Doctoral Internship Program with STEM components

The specific features of the intensive doctoral program with STEM components are determined by the achievement of the following objectives: training of highly qualified scientific and research staff with skills to carry out theoretical and experimental activities; creation and distribution of new scientific products; maintaining a high level of awareness of the academic staff and the doctoral students about the most important world achievements of science; contribution to scientific-theoretical and practical knowledge, skills to carry out independent research activities and to work in a team.

The practical courses and subjects of the Intensive Doctoral Internship Program include STEM components (Science, Technology, Engineering and Mathematics). Special attention is directed to acquisition and/or strengthening practical skills such as: working with modern CAD systems, with

ABAQUS, ANSYS, MATLAB, and Simulink.

These courses apply a relative new approach for teaching and developing creative thinking that builds skills to solve real problems and contribute to creating scientific modelling and simulation.

Based upon the experience of the University of Ruse in working in partnership with industry companies, this institution is able to offer an international internship for incoming Erasmus PhD students in the university laboratories donated by these companies.

The University of Ruse has an established university library, which is one of the largest scientific libraries in Bulgaria. It functions as a center for scientific and informational resources, which supports the learning process and scientific research activities by offering modern library services. The library has a collection of 421 560 volumes: 341 855 books and 45 444 journals. The electronic catalog of the academic library and the general electronic catalog of the Academic Regional Library Information Network make it possible to consult the literature available in the library from any workplace and outside the university. Therefore, a theoretical literature research at the University of Ruse could be very beneficial for the PhD students participating at the Doctoral Internship Program.

4. RESULTS AND OUTCOMES EXPECTED

The different courses and subjects of the Intensive Doctoral Internship Program are based on contemporary achievements of scientific research in the field of STEM, (Dobreva, 2013), (Dobreva & Pavlov, 2021), (Kamenov et al., 2017), (Stoyanov et al., 2021).

The specific features of this Doctoral Internship Program facilitates the achievements of following results and outcomes: highly qualified scientific and research staff with skills to carry out theoretical and experimental activities; providing opportunities to create new scientific products and achieve significant scientific results; building contemporary theoretical and practical knowledge and skills to carry out independent research activities; ensuring options for working successfully in a team.

5. CONCLUSION

Based upon the research presented, the following conclusions can be deduced:

The Department of “Machine Science, Machine elements, Engineering Graphics and Physics” at the Transport Faculty at the University of Ruse has experience in supervising doctoral students and for implementing International Summer Internship within Erasmus plus program. Therefore, the Intensive Doctoral Internship Program is to be implemented successfully during the next several years.

The International Doctoral Internship Program is open to PhD students from all European universities and it is expecting to fulfill its main objectives: to support the scientific research of PhD students and to improve and upgrade doctoral students' practical skills in the area of Science, Technology, Engineering and Mathematics.

6. ACKNOWLEDGMENT

The authors would like to express appreciation for the support of the the Scientific Research Funds of the University of Ruse, Bulgaria. The research work done is realized in framework of several scientific seminars at the Department of “Machine Science, Machine elements, Engineering Graphics and Physics” at the Transport Faculty at the University of Ruse. The support is gratefully acknowledged.

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https://www.uni-ruse.bg/en/education/phd

K-12 EDUCATIONAL SOFTWARE TECHNOLOGY

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1. INTRODUCTION

This research work presents finding following a three academic years period of face-to-face classroom interaction with K-12 students introduced to programming and robotic programmable devices. An outline of the development process towards establishing an accredited teaching module is being presented along with developed materials both in terms of hardware and software. Results being discussed analyze the ability of three different group ages [6-8), [8-10), [10-12) to cope with guided building of robotic devices, to devise algorithms for problem solving and to implement algorithms via programming.

2. MATERIALS AND METHODS

Materials used, although not limited to, invoke Lego WeDo2 [Evripidou et al., 2018] programmable robotic construction kits. These were selected as they are easily depicted as toys by the young agers' students casting a sense playing and learning at the same time. Furthermore, due to critical ages safety of use had to be ensured so wireless communication with personal computers was assured with the use of low energy dongles. Structured programming was conducted using Scratch 3 programming environment developed and freely disseminated for teaching and learning purposes by MIT [Smith, 2022].

Teaching materials developed support an agile learning approach [Salza et al., 2019] where students learn by problem solving, trial and error, evaluation, re-evaluation and adjustment aiming to develop two very critical skills, individual learning and analytical thinking. A certain learning cycle [Lang, 2017] is being repeated during each sprint (short set of exercises) comprised of planning a solution to tackle a problem, design an algorithm on how to do that, develop and test that algorithm every step across its way, deploy the algorithm and revise its outcomes, assess and reassess till finally executing the end product.

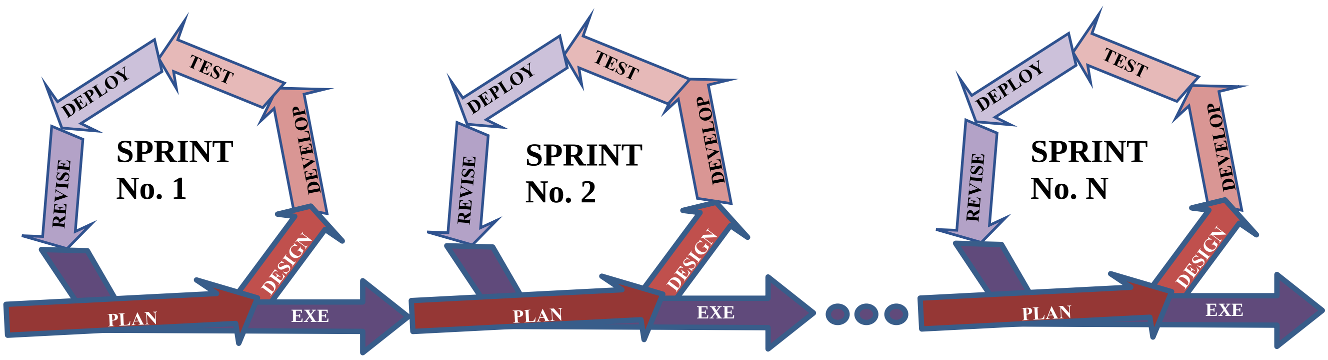
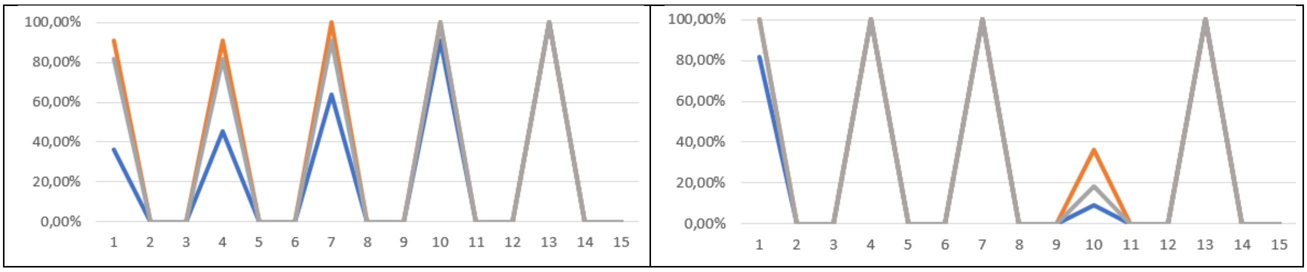


Figure 1. The agile learning cycle used for programming educational robots.

Classes were conducted both in primary schools and in the educational robotics laboratory of the Centre of Education and Life Long Learning of the Hellenic Mediterranean University in Chania, Crete, Greece. Primary efforts were conducted in [8-10) year old students at the 10th Primary School of Chania with the target to enter, as did happen, the 2018 World Robot Olympiad, which helped test, revise and refine teaching matterials. Next academic year just short of the latest pandemic, with the approval of the Institute of Educational Policy of the Greek Ministry of Education, lessons were conducted to primary schools for nearly a full month to ages [8-10) and [10-12). Following the end of strict measures due to the pandemic, the program run independently during the last academic year by the Centre of Education and Life Long Learning of the Hellenic Mediterranean University for students aged [6-8), [8-10) and [10-12) at the laboratory of educational robotics counting thirty students overall, ten at each group of age.

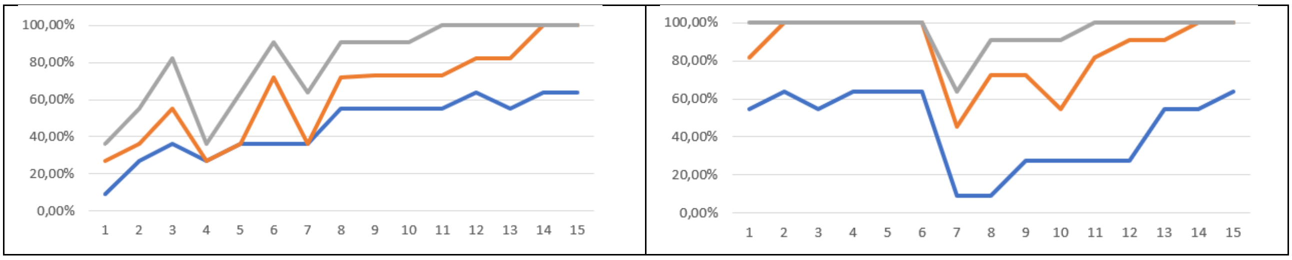
3. RESULTS AND DISCUSSION

The following figures present results regarding the assessment of students performance for each different age group in three different categories, guided construction of an educational robot, b) understanding the system and c) design and implementation of a structured program using Scratch 3. Results are presented as percentages to the overall attendance to compensate for the occurred students' absences.



(a) **(b)**

Figure 2. Student performance in guided robot construction.
(a) first 5 sprints of a 15 week time period, (b) last 5 sprints of a 15 week time period with less tutor guidance.
[6-8) blue line, [8-10) orange line, [10-12) gray line



(a) **(b)**

Figure 3. Student performance in system understanding.
(a) first 5 sprints of a 15 week time period, (b) last 5 sprints of a 15 week time period with less tutor guidance.
[6-8) blue line, [8-10) orange line, [10-12) gray line

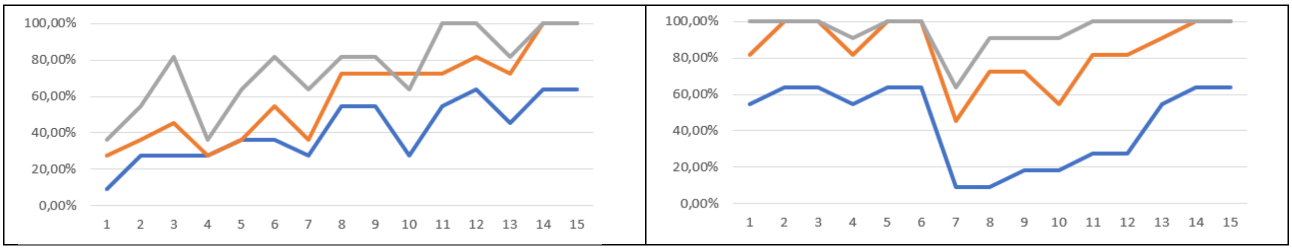


Figure 4. Student performance in guided structured Scratch programming.
(a) first 5 sprints of a 15 week time period, (b) last 5 sprints of a 15 week time period with less tutor guidance.
[6-8) blue line, [8-10) orange line, [10-12) gray line

From the above results seveal worth noting observations arise. Students age [8-10) and [10-12) are performing comparatively more or less the same. The students' group aged [6-8) tends to fall behind but this more due to the difficulty of reading and understaning whta they have read on the computers console fast enough with respect to older students rather than designing and inplementing an algorithm. All group ages were shocked at the beggining of the secong 15-week sprints were tutors intervention and guidance was deliberately considerably reduced. It took students two to three sprints to recover from the shock and also to realise that they can do it just by themselves via teamwork. All group ages managed to cope fully durin the last two sprints of the second 15-week sprints cycle.

All students were very capable of following instructions in constructing educational robots. In terms of systems understanding all three age groups were able to cope after the first three sprint of the first guided learning cycle. All age groups realised the esense of inputs and outputs to and from a system in the form of sensors and actuators, respectively. Even in the second less guided 15 week cycle, system understanding was the agile learning part that puzzled them less.

In terms of structured programming with Scratch 3, the age group [6-8) managed to cope with serial algorithms, branches and loops. Age groups [8-10) and [10-12) exceeded expectations and were able to undestand boolean variables, variables and secondary assistive functions, with the [10-12) group slightly performing better than the [8-10) group. All groups managed to break larger problems into smaller milestones and devise, design and implement partial and overall algorithms with guidance during the first 15-week cycle. All three groups struggled considerably with that task in the secong less guided 15-week learning cycle and specifically for the [6-8) age group guidance was again deemed necessary at full. For the groups aged [8-10) and [10-12) some students managed to cope by themselves better than others, yet some guidance was once more deemed necessary.

4. CONCLUSIONS AND FURTHER WORK

The emergent need in software engineering and emergent technologies requires a drastic down-propagation of programming skills development and understanding of programmable devices to ages under the K-12 band starting as early as the first classes in primary schools. Similarly to maths and languages students can develop skills such as analytical and algorithmic thinking. The above test case demonstrates that K-12 students can cope with some guidance with educational robotics both in terms of constructions and programming. K-12 students can realise the meaning of sensors and actuators and thus understand what inputs and outputs to a system are. Also, K-12 students appear capable of implementing structured programming algorithms to produce a solution to a problem. Even more important agile learning and educational robotics enable students realise that programming affects the outer world and not just the console of their computers; and helps them learn via trying to solve a true real life problem learning in the process by attempting, evaluating, adjusting and trying again till the final goal has been achieved. This approach promotes a most valuable can do attitude.

In further work, the authors aim to invoke affective computing [Yun et al., 2022] applications during real time classrooms. The target is to assist the agile learning process and the tutors involved with a real time notification of feelings depicted by individuals of group of K-12 students while working on a learning sprint. This should pass valuable information of joy, anxiety, boredom, success, neutrality etc, to the tutors in real time during the class allowing them to intervene and pass praise or act accordingly to resolve or excel an ongoing learning situation.

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