SMART 2019

The Eighth International Conference on Smart Cities, Systems, Devices and Technologies

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Nice, France

SMART 2019 Editors

Lasse Berntzen, University of South-Eastern Norway, Norway

SMART 2019

Forward

The Eighth International Conference on Smart Cities, Systems, Devices and Technologies (SMART 2019), held between July 28, 2019 and August 02, 2019 in Nice, France, continued a series of events covering tendencies towards future smart cities, specialized technologies and devices, environmental sensing, energy optimization, pollution control and socio-cultural aspects.

Digital societies take rapid developments toward smart environments. More and more social services are digitally available to the citizens. The concept of 'smart cities' including all devices, services, technologies and applications associated with the concept sees a large adoption. Ubiquity and mobility added new dimensions to smart environments. Adoption of smartphones and digital finder maps, and increasing budgets for technical support of services to citizens settled a new behavioral paradigm of city inhabitants.

The conference included academic, research, and industrial contributions. It had the following tracks:

- Mobility monitoring and control in smart environments
- Digital cities

We take here the opportunity to warmly thank all the members of the SMART 2019 technical program committee, as well as all the reviewers. The creation of such a high quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and effort to contribute to SMART 2019. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

We also thank the members of the SMART 2019 organizing committee for their help in handling the logistics and for their work that made this professional meeting a success.

We hope that SMART 2019 was a successful international forum for the exchange of ideas and results between academia and industry and to promote further progress in the area of smart cities, systems, devices and technologies. We also hope that Nice, France provided a pleasant environment during the conference and everyone saved some time to enjoy the charm of the city.

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Design of Non-Destructive Evaluation Robot Using Magnetic Flux Leakage for Main Water Pipe

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***Abstract*—Many infrastructures in the world include pipe systems, e.g., gas, oil, water, electricity, air circulation, etc. Using a pipe system for the delivery of such materials allows for easy human control. However, if the pipe is broken or contaminated, the process is disturbed and the risk cost for the society can increase substantially. For instance, contaminations in fluids like air and water may result in spreading of diseases. Therefore, maintenance of the pipe is crucial. For a long period of time, identification of a pipe requiring a repair only depended on its installation time because its condition was not exposed until the pipe was destructed or cut. Recently, non-destructive evaluation technology and robotics are changing the paradigm of the identification process. Maintenance technicians can identify faulty pipes from reliable data, collected directly from the pipes, instead of relying on the pipe's installation period. In this paper, we propose a robot design with Non-Destructive Evaluation (NDE) for waterwork pipes.**

Keywords-main water pipe; waterworks; pipe; robot; NDE; MFL.

I. INTRODUCTION

A well-founded infrastructure plays a major role in city development. The infrastructure is composed of systems such as roads, electrical grids and water supply pipes. These systems are the power sources running the society. If one of the systems malfunctions, the society suffers from inconvenience and the productivity drops. Therefore, monitoring the conditions and maintenance of the infrastructure are directly correlated with the functionality of the society.

This paper discusses a design of NDE in-pipe robot for main water pipe. Many robots have already been used in water pipes [1] with various inspection technologies [2]. Among the various attributes of such robots, this research focuses on mobility using the Magnetic Flux Leakage (MFL) method [3].

The majority of existing NDE systems attempt to cover the whole pipe surface at the same time [4]. In order to cover the entire inner surface of the pipe, the system often requires a large number of attached sensors through the entire pipe. Our proposed design decreases the complexity by moving the sensors along the direction of the robot's movement. Also, to reduce the weight of the robot, our team considered a moving sensor as in the Diakont robot [7], which uses Electromagnetic Acoustic Transducer (EMAT). While this type of sensor increases the difficulty of the signal processing, our robot can still benefit in mobility by a reduction in the number of sensors. The robot can also smoothly carry the NDE modules at an inclined pipe, vertical pipe, elbow, and miter type pipe.

Additionally, there are two advantages using the MFL method. First, it is radiation free. Second, the method can be used to sense the magnetic field without the medium. These characteristics minimize possible water pollution that can occur during the pipe inspection.

Through this paper, we complete a complete design of the proposed robot. However, the future goal of the project is to make a system with MFL modules moving in spiral motion (Figure 1) when facing various obstacles. Consequently, the robot will be applied to real water main pipes. The results show the possibility of overcoming different obstacles present in pipes and a city will be able to have integrated control for maintenance of the pipes.

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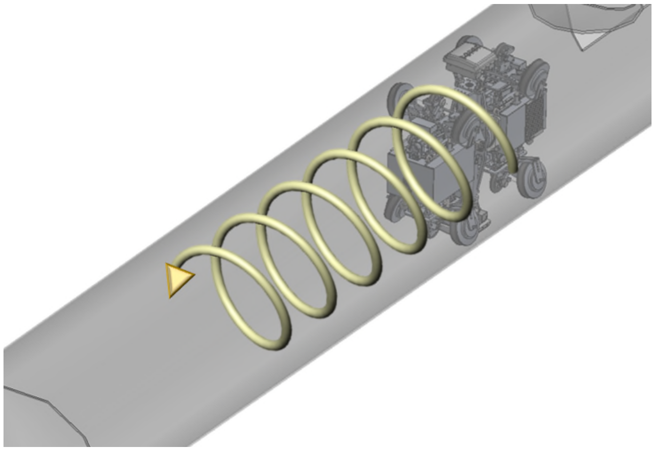

Figure 1. Example of the spiral motion of MFL modules.

II. DESIGN

A. System Overview

The targeted performances of the robot in this paper are stable spiral motion of the MFL modules and successful climbing of a 22.5° slope. We chose spiral motion because the spiral motion enables the robot to inspect the surface of the pipe with the minimum number of the MFL modules, resulting in a low system cost (weight, volume, power). The 22.5° slope is chosen because this is the value for the majority of water pipes in Republic of Korea.

To fulfill the set goals, the robot requires rotation, attachment and detachment actuators for the MFL module. A linkage system with sufficient wheel grip force is also required. Additionally, an odometer is required for locating the defects. Electrically, for the locomotion of the robot and visual inspection of the pipe condition, camera, Inertial Measurement Unit (IMU), Light Detection and Ranging (LiDAR), Single Board Computer (SBC), and Data acquisition (DAQ) for the MFL are installed as in Figure 2. Finally, the robot size is 1100 x 840~1100 x 300 (mm, L x H x W; height is changeable to adapt to the ovality of the pipe). The total weight is about 160 kg.

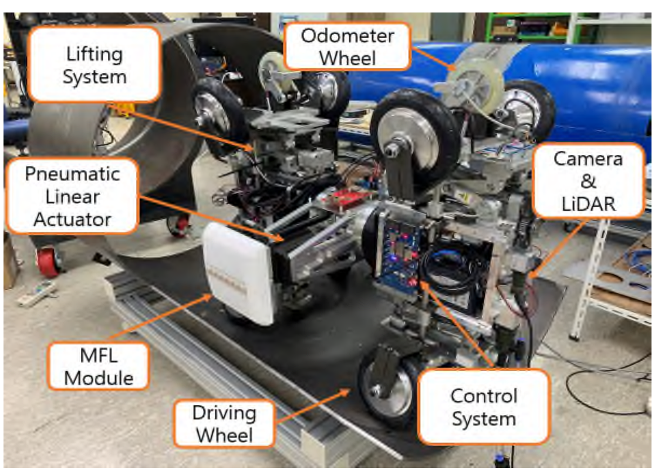

Figure 2. Components of the robot.

B. Free Body Diagram

Using free body diagram of the concept design and understanding about the system, the power of actuators effected by the attraction force of MFL and weight of the robot can be derived. MFL consists of magnet, hall sensor, front-back shoe, and Polytetrafluoroethylene (PTFE) cover, as shown in Figure 3. The hall sensor senses leakages of the magnetic field caused by reduction in pipe wall thickness. The PTFE cover is used to decrease the friction between the pipe and the MFL module.

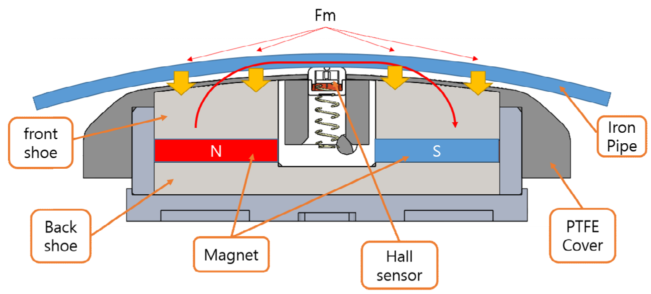

Figure 3. The MFL module section view: Shoes help to make closed magnetic field.

As depicted in Figure 4, the external forces are traction, drag force and weight. The traction force (F_{rt} : required traction force) is decided by the torque driving the wheel and the wheel grip force. The grip force is caused by the normal force on the wheel from the surface. The drag force of the MFL (F_{md}) is generated from the attraction force of magnet (F_m). The F_m can be calculated by (1). The size of the magnet is 150x56x10 (unit mm, L x W x H) and flux density is about 0.4 T (Tesla). The friction coefficient for PTFE and steel is about 0.2 [5]. Eventually, F_m and F_{md} are 2400 N and 480 N, respectively, because of two MFL modules. Additionally, on the slope, the weight of the robot creates a drag force. Therefore, considering the target acceleration motion, the required traction force can be obtained by (3), (4):

$$F_m = (B^2 \cdot A)/(2\mu_0) \tag{1}$$

B: flux density

μ_0 : the permeability of space($4\pi x10^{-7}$)

A: the area of each surface

$$F_{md} = \mu \cdot F_m \tag{2}$$

$$\Sigma F = ma = F_{rt} - F_{wx} - F_{md} \tag{3}$$

$$F_{rt} = ma + F_{wx} + F_{md} \tag{4}$$

The velocity and acceleration of the robot are 300 mm/s and 150 mm/s^2, respectively. The F_{rt} is about 1100 N. To generate the force, a torque of a wheel motor must be 33 Nm under the condition of eight wheels, 250 mm wheel diameter, and friction coefficient $\mu \fallingdotseq 0.6$ between rubber (wheel tire) and steel [6]. For a stable locomotion, the non-slip condition of the wheel has to be considered. The condition states that the traction force generated by the

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wheel torque should be smaller than the friction force of the tire (F_{nt}) created by the weight (refer to (5)). The current F_{nt} (680 N) is smaller than F_{rt} from (6). For a non-slip motion, F_{wy} can be increased by pushing on the pipe wall.

$$F_{nt} \geq F_{rt} \tag{5}$$

$$F_{nt} = \mu \cdot F_{wy} \tag{6}$$

Therefore, the minimum non-slip traction force is F_{rt}, which can be calculated from (7). Equations (8), (9) represent the traction force of the bottom and upper wheel, respectively.

$$Fnt = \mu \cdot (Fwy + F'p) + \mu \cdot Fp \tag{7}$$

$$Fbt = \mu \cdot (Fwy + F'p) \tag{8}$$

$$Fut = \mu \cdot Fp \tag{9}$$

$$Fp = F'p \tag{10}$$

$$Fp \geq (Frt - \mu \cdot Fwy) / (2 \cdot \mu) \tag{11}$$

By using F_p (380 N), upper (6 Nm) and bottom (27 Nm), the wheel torque is also calculated.

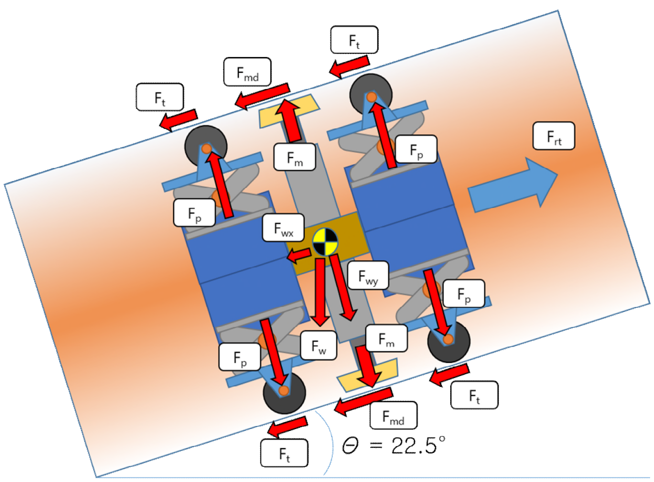

Figure 4. The free body diagram for understanding applied forces

C. *Simulation for Driving Wheel Torque*

To verify the result from the Free Body Diagram (FBD), we use a multibody dynamic analysis simulation tool: DAFUL [8]. Conditions used in DAFUL are equal to the values from the FBD, such as weight (1600 N), push force (380 N), drag force by MFL (480 N), and slope (22.5°), as in Figure 5. We are interested in the required torque in a wheel. Under these conditions, by substituting the target velocity of the wheel, DAFUL shows the resulting torque about the wheel. The average values for upper and bottom wheel are 20 Nm and 110 Nm, respectively. The robot system has eight wheels in total, 4 at the top and 4 at the bottom. Therefore, one top wheel needs about 5 Nm and one bottom wheel needs about 27 Nm, see Figure 6. The simulated values are shown to be very similar to our FBD results.

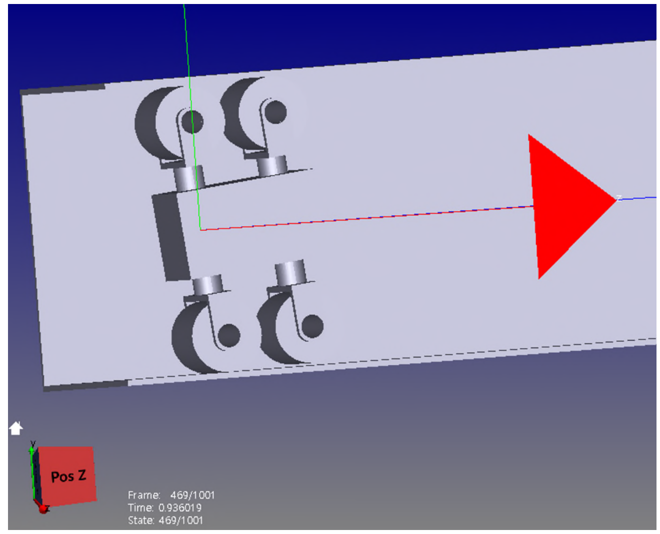

Figure 5. Simple modeling at the DAFUL

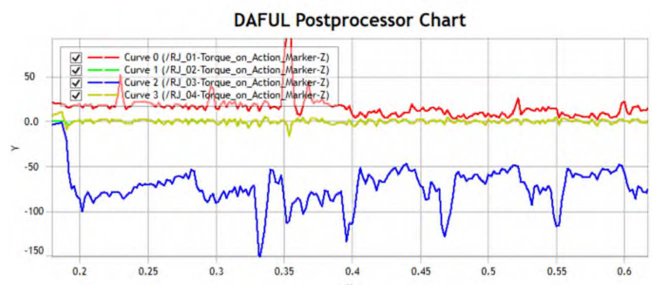

Figure 6. Results of Time (s) – Torque (Nm): the average of blue chart is about 27 Nm and red chart is about 5 Nm

D. *MFL Rotation and Attachment Mechanism*

MFL sensor modules have spiral motion with attaching condition on the pipe wall. It creates the friction force to be in a distracting rotational direction, as shown in the free body diagram section. The rotational torque can be found using equation (12):

$$\tau = d \times F_{md} \tag{12}$$

F_{md} from the two MFL modules is about 480 N and the torque is about 240 Nm. The pipe diameter is 1000 mm and the axis of rotation of the MFL is at the center of the pipe.

To sustain the torque and rotational velocity (30 rpm), a motor has to generate about 0.75 kW of power.

However, due to the large power source and motor volume, we try to generate detachment force (F_d) rather than turning to high power motors. The detachment force reduces the total MFL drag force from (13).

$$F_{md} = \mu \cdot (F_m - F_d) \tag{13}$$

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To generate the F_d, pneumatic linear actuators are applied (Figure 7). Using calibrated pressure, the actuators are able to fully detach the MFL from the pipe wall or reduce the F_{md}.

The actuator is designed to generate a detachment force up to 1600 N at 0.65 MPa. By using the actuator, F_{md} decreased to 400 N resulting in a total required torque of 80 Nm and a motor power of 0.25 kW.

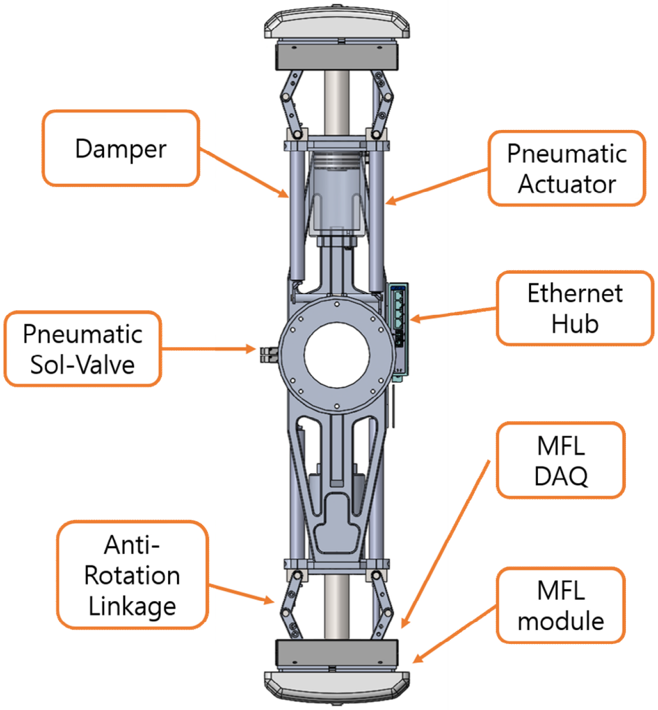

Figure 7. Rotating module: the MFL module and DAQ for sensing, Ethernet hub for transferring the sensing data to server, sol-valve for controlling the actuators, damper for reducing the sudden motion made by magnetic force

The MFL module can rotate infinitely which may twist the power and communication cables and air hose. To avoid the twist, a slip ring is applied and swivel manifold are specially designed. The swivel type causes the friction on the seal, which depends on the compressed volume of the O-ring. In our design, the volume is kept at half of the maximum recommended by the manufacturer, to decrease the friction, as in Figure 8.

Due to the decrease in the F_{md}, the required wheel torque is also decreased to 1 Nm (upper) and 22 Nm (bottom), allowing the choice of general hub motor.

E. Driving Wheel Attachment Mechanism

For a stable locomotion, wheels require a mechanism that creates a push force and conform to a rough pipe surface. A scissors mechanism is designed to lift the robot and push against the wall for stable attachment. The reaction force is the sum of push force and weight (14). The force is about 2000 N, weight 1600 N and push 380 N.

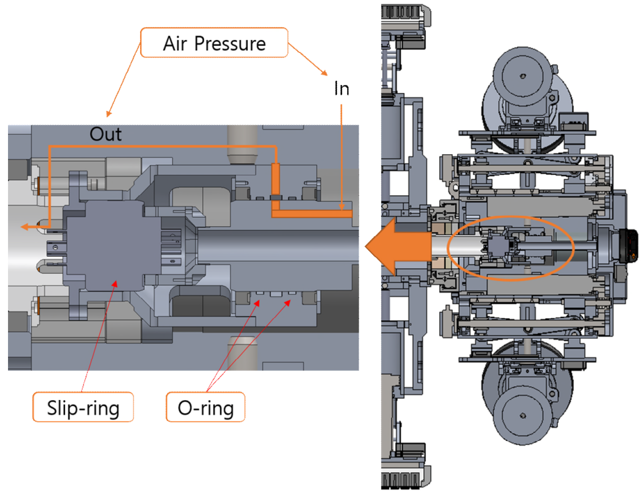

Figure 8. MFL modules rotating hinge mechanism

$$F_l = F_w + F_p \tag{14}$$

To generate the force, the mechanism (Figure 9) uses a ball screw which requires about 0.6 Nm of torque.

Because the ball screw cannot be driven backwards, the feedback current of the motor cannot be used to conform to the rough pipe surface and welding bead. In order to overcome this issue, we apply the load cell to directly read the external forces changed by pipe conditions.

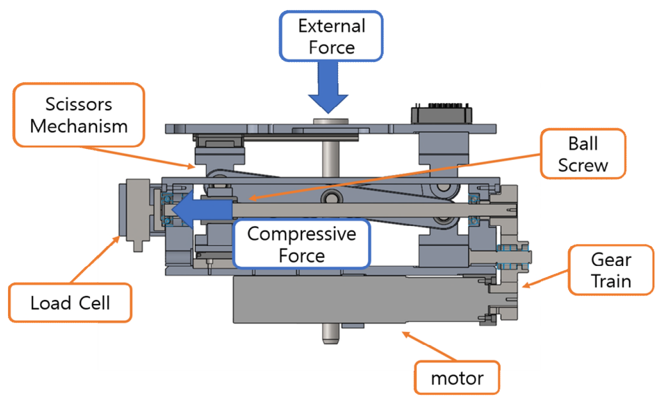

Figure 9. Wheel attachment mechanism

III. CONCLUSION

This project aims to design and verify robot mobility and motion of the sensors needed for a large water pipe inspection. As the result, we design a robot system that can climb a 22.5° slope and generate spiral motion for the sensors. The key design factor is the use of the pneumatic actuator. Using the compressibility of the air, compliance, control is made simple without additional force-torque sensor, complex system modeling and control strategies compared to motor based systems. Additionally, because of reduced magnetic attractive force, the system's weight, volume and power consumption can be decreased with a low powered motor.

For the future work, we aim to overcome additional obstacles, such as 45° and 22.5° miter type bend, water, and spiral weld bead. Based on this research and development, we will design another robot system that will be able to overcome the additional obstacles marked in Figure 10. We will also develop an algorithm to find defects from data generated solely by the two MFL modules in spiral motion.

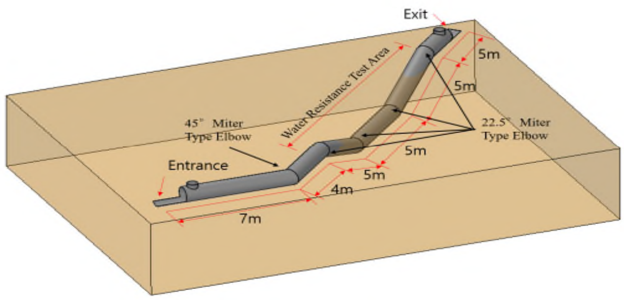

Figure 10. Final robot test bed: obstacles: 45°, 22.5° miter type elbow, water section, about 30 m distance.

ACKNOWLEDGMENT

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Sequencing Intelligent Components through Releases as a Risk Reduction Strategy: a Smart-city Example

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***Abstract*—In Component-Based Software Engineering, the process of selecting software components is under several risk factors. Traditionally, these have been identified or mitigated with software project management techniques. However, the new demand for intelligent systems has added complexity to the process. Despite the success and technological advances of this type of systems, their development in an environment ready for production remains a challenge. There is a considerable number of technical issues that limit their adoption, and their selection determines the introduction of new risk factors, different from traditional ones. In this paper, we present the following idea: given a set of requirements for one component - intelligent behaviour, for example - we propose to sequence and replace different components through evolving releases as a risk reduction technique, instead of choosing the option of only one "right" component. Using a systematic mapping literature review, we gather the main risks of intelligent components. Then, we present a formalization of the risk-based component selection technique. Finally, we offer an example to illustrate our approach using a sequence of intelligent software components in the context of an air pollution forecasting system.**

Keywords–Intelligent components; Component Selection; Component-Based Software Engineering; Risk Management.

I. INTRODUCTION

The Component-Based Software Engineering approach is based on the idea that software systems can evolve by selecting and aggregating appropriate software components [1]. Some of the recognized advantages of this approach are: (1) faster development, since assembling new applications through existing components reduces development time; (2) easier to maintain, since managing one component at a time makes maintenance easier; (3) improved quality, since each component is tested before releasing it; (4) easier to create applications variants and upgrades, since changing or upgrading each component separately is simpler; and (5) lower overall development cost, since the development cost is reduced by handling or upgrading information systems separately [2].

When a software-intensive system is evolving, the process of deciding which component to use involves different available sourcing options, such as internal development, outsourcing, buying a commercial component or adopting some open source component [3]. Several factors have already been identified, in order to select a specific component: size, cost, maturity (years, versions), compatibility, and adherence to standards, among many other nonfunctional requirements [3]–[5].

Risk management is a classical area in Project Management discipline covering not only projects but also programs and portfolios [6]. Risk management implies to manage potential events which would (negatively) impact long-term strategic objectives and projects' objectives, i.e., cost, time and scope. In software engineering, risk management has been a topic of growing relevance through time, and different risk factors have been identified, such as analysis, design, coding, testing, planning, control, contracts, teams, clients, policies and structure [7]. In relation to Component-Based Software Engineering, the risk is moved from classical waterfall stages and their management to component-based stages and their management, i.e., to component seeking, selecting, and testing.

While the field of Component-Based Software Engineering has identified ways to help select a software component using prioritization factors, there are new considerations and challenges to overcome due to the intelligence software era [8]. This intelligence software era brings systems that are known as systems that can automatically improve through experience [9]. The successes of the artificial intelligence field are visible, for example, in domains such as computer vision (e.g., object recognition [10]), natural language processing (e.g., information extraction [11]), and sound analysis (e.g., voice recognition [12]). Diverse applications became part of products of big and famous companies, such as Facebook, Google, and Apple, producing a closeness effect between people and artificial intelligence which has brought a new set of demands to software production.

Therefore, despite the success and technical advances in intelligence systems, its development in a production-ready setting still remains challenging. There is a lack of tools and software engineering practices for building such systems, especially if the company/organization does not have an experienced machine-learning research group and a data-oriented supporting infrastructure [13]. For example, let us consider the selection of a machine learning component to enable a weather forecasting functionality. This component may include specifications about hardware (e.g., Graphics Processing Unit (GPU) models), platforms (e.g., machine learning, deep learning library dependencies), source code (e.g., prepossessing, glue code), configuration (e.g., model features configuration), training data (e.g., sample period), or model state (e.g., version of training model) [14]. This set of attributes differs from traditional prioritization factors, adding complexity to the selection process, and therefore risks.

To address the challenges presented above, in this article, we present an approach based on software components, which allows managing the risk involved in selecting complex software components, such as those that provide intelligent

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behaviour. The contributions of this work are the following: (1) we identify the intelligent component risks by conducting a systematic mapping literature review; (2) we introduce a formalization of the problem of risk in the process of software components selection; (3) we present a selection sequence technique, from low to high risk, with a growing scenario of requirements; and (4) we illustrate the proposal by presenting the case of a plan for implementing an air pollution forecasting system as part of a Smart-city project.

The remainder of this paper is organized as follows. In Section 2, we collect information for establishing the risky points of intelligent components, by applying the systematic mapping protocol. In Section 3, we present a general framework for selecting a sequence of components in place of only one and the constraints for this choice. In Section 4, we apply the general proposal by showing a scenario of the selection of an intelligent component that enables an air pollution forecasting functionality. Finally, in Section 5, we conclude with benefits and limitations.

II. OPEN ISSUES ON SELECTING AND ADAPTING INTELLIGENT COMPONENTS

To investigate the risky points when developing, selecting or adapting intelligent software components, we analyze the state-of-the-art of related software engineering challenges. Our goal was to understand what are the software engineering challenges, how they have been addressed, as well as the context where they occur. To achieve that, we perform a systematic mapping review (following the guidelines of [15] [16]).

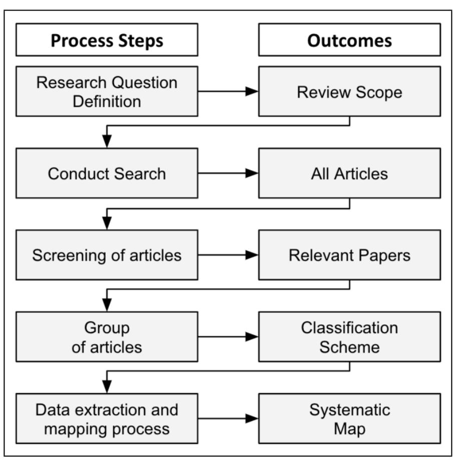

Figure 1. Systematic mapping review process. Adapted from [16].

Figure 1 gives an overview of how we developed the study. First, we formulated research questions keeping in mind the problem of unknown challenges when developing intelligent software components. Second, we searched for articles in digital libraries. The search included the search keywords, the temporal interval of papers and the type of bibliographic source. Third, we defined and applied the inclusion and exclusion criteria to select articles. Fourth, we described the classification scheme built with the selected articles. Finally, we ordered the selected articles and generated a systematic map.

A. Research question definition

We defined the following main research question (RQ): what are the software engineering challenges when developing, selecting or adapting intelligent software components? In our research scope, we considered answering this question by reviewing studies that present analysis, reviews or case studies that overview software engineering challenges related to the development of intelligent software components.

B. Executing the search

We executed the search by intersecting and joining keywords in the following search string: (‘machine learning’ OR ‘artificial intelligence’ OR ‘autonomous’ OR ‘deep learning’) AND (‘systems’ OR ‘applications’ OR ‘components’) AND (‘software engineering challenges’). We utilized four library sources: (1) Science Direct [17]; (2) IEEE Digital Library [18]; (3) ACM Digital Library [19]; and (4) Springer Link [20]. Complementary, we also looked for articles in Scopus bibliographic database [21] as a form of verification, and to expand the search spectrum. In all cases, we looked for articles between the years 2014 and 2019 (March). As a result, we gathered a total of 615 articles.

C. Screening of articles

To screen and review the gathered articles, we defined and applied inclusion and exclusion criteria. Our inclusion criteria considered primary and secondary studies published in chapters of books, journals and scientific conferences. As exclusion criteria, we did not consider articles with: (1) research context out of our scope; (2) a language other than English used; (3) specific application domain (e.g., telecommunication; energy, medicine, etc.); (4) duplicates and conference proceedings summaries; and (5) no full article text available. After applying the inclusion criteria, we selected a total of 9 relevant articles. Also, the exclusion criteria allow us to select a total of 4 articles. In this phase, we also included a snowballing article selection technique (following the guidelines of [15]). This technique gave us a total of 5 new relevant articles. We also decided to add 8 articles manually. These articles come from relevant conferences, like The First Symposium on Software Engineering for Machine Learning Applications [13] and domain experts from Google. Finally, we got a total of 17 selected articles.

TABLE I. SUMMARY OF GATHERED ARTICLES BY CRITERIA AND STAGE PART I.

	ScienceDirect	IEEE	ACM
Initial search	14	4	8
Inclusion criteria	0	2	1
Exclusion criteria	0	1	1
Snowballing selection	0	1	0
Total after criteria	0	2	1
Manually added	-	-	-
Final total	-	-	-

A summary of gathered articles by criteria is available in Table I and Table II (The data was divided in two tables for readability).

D. Grouping the articles

Once we finished the previous phases, we defined a classification scheme based on three subjects related to software engineering challenges: (1) Software Life Cycle Phase, which concern the software life cycle phases involved. Here, we included specification, development, verification and validation, and evolution phases. Also, we included project management as a way to categorized related project development issues; (2) Proposals, to investigate how the challenges have been addressed. That includes development approach, project management, adjustment, measurement strategy, tool development, team diversity or no strategy; (3) Context, to investigate where the challenges have happened. We considered the academy, big industry (e.g., Google or Apple) or small industry (e.g., online or startup companies).

TABLE II. SUMMARY OF GATHERED ARTICLES BY CRITERIA AND STAGE PART II.

	Springer	Scopus	Total
Initial search	45	544	615
Inclusion criteria	0	6	9
Exclusion criteria	0	2	4
Snowballing selection	0	4	5
Total after criteria	0	6	9
Manually added	-	-	8
Final total	-	-	17

E. *Data extraction and mapping process*

We completed the systematic mapping review by generating a summary study map (Figure 2). We were able to identify three categories with associated papers: (1) development; (2) evolution; and (3) project management. In each of these categories, there exist software engineering challenges that we summarize in Table III.

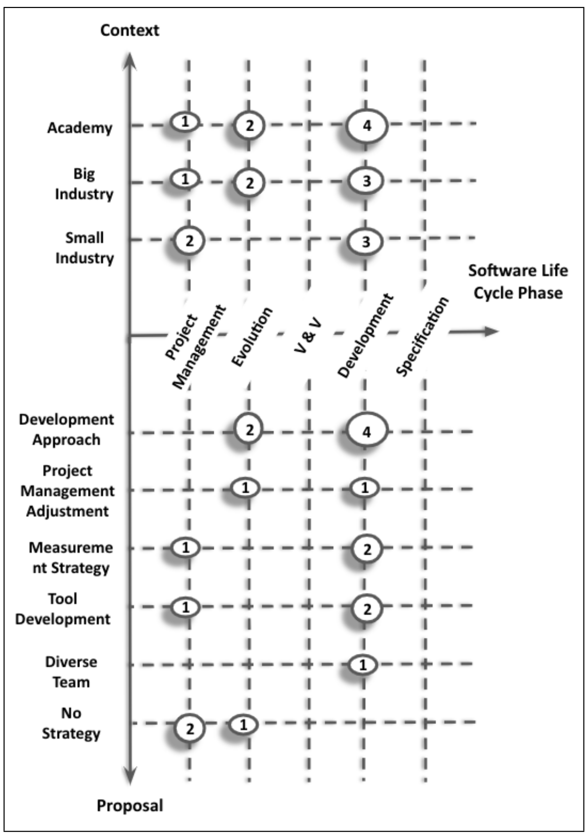

Figure 2. Summary study map.

The Development category includes the following software engineering challenges (or open issues): (1) Experiment Management, to manage a large number of experiments performed when identifying an optimal model. In this experimental process, it is necessary to guarantee reproducible results [14] [22] [23]; (2) Transparency of Machine Learning Models. Complex models like large neural networks used in fields, for example, computer vision or natural language processing are difficult to explain, and thus, transparency is traded for accuracy [13] [14]; (3) Difficulties in estimating the results of intelligent software components before they have been trained and tested [24] [25]; (4) Resource Limitation, concerning specific requirements of distributed systems to manage large volumes of data, the computational needs for extracting and transforming data, training and evaluating a model, and serving the model in production [14] [24]; (5) Testing, related to the need for tools which allow test static data and production data, machine learning models and production-ready components [22] [24] [26]; (6) Data Processing, when working with distributed systems, adds complexity in several dimensions. It requires additional knowledge, time to operate the systems, management and resources associated with hardware and software [14] [24]; and (7) Development Team, concerning how diverse a software development team must be. This list covers different aspects of developing an intelligent component [23] [27] [28].

The Evolution category includes: (1) Issues with Dependencies, that is data, hardware, machine learning frameworks or models dependencies [28] [29] [30]; (2) Hidden Feedback Loops; this phenomenon happens when the data adapt the model and not backward, especially in production-ready systems [14]; (3) Monitoring Deployed Systems that refers to the need to maintain a deployed machine learning system over time. Usually, teams fail to recognize the effort needed [14] [23]; and (4) Glue Code and Supporting Systems that refers to systems with a small part of the code belonging to the intelligent component. Here, the rest is "glue code" that interacts with supporting systems, and thus, the system becomes hard to test [14] [31] [32].

TABLE III. OPEN ISSUES/SOFTWARE ENGINEERING CHALLENGES

Category	Challenges / Open Issues
Development	Experiment Management Transparency of Machine Learning Models Difficulties to Estimate Results Resource Limitation Testing Data Processing Development Team
Evolution	Issues with Dependencies Hidden Feedback Loops Monitoring Glue Code and Supporting Systems
Project Management	Effort Estimation Privacy Data Workflows

Finally, the Project Management category includes: (1) Effort Estimation. When developing intelligent software components, the goals might be unclear, and an expected-results definition is challenging. Also, other properties like acceptable performance definition are hard to set beforehand [28] [33] [34]; (2) Privacy of the Knowledge of a System, that refers to how to store the data across the weights of a machine learning model. This information is hard to manage when there is a lack of model understanding. It forces companiesto have terms of service agreements and to use anonymized or aggregated statistics of the user data [13] [14] [23]; and (3) Data Workflows that required to handle the volume, variety, and the velocity of a large amount of data [33] [35] [36].

The final list of software engineering challenges involves a risk every time that there is a lack of adequate associated techniques. However, to present our proposal, we formulate a formalization in the next section.

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III. Sequencing components as risk reduction strategy

In this section, we present a theoretical point of view of the problem of the selection of several components in place of selecting only one. Regarding this topic, the main focus of the literature is on how to select one component for a specific set of requirements. Here, the methods and techniques for decision making are qualitative approaches [5] [37] [38]. To the best of our knowledge, there are no proposals considering the redundancy of components for the same set of requirements, and there are not proposals considering components' risks. In this context, we consider that most of the quality factors are uncertain factors because the expected quality occurs in the best case, once the component has been successfully integrated. This perspective manages not only quality factors but traditional uncertainties, such as total time and budget.

In this proposal, we keep one of the main assumptions of other authors, that is, we decide what components to select before the test and try cycle. Risk perspective accepts that the uncertainty of a project is higher at the beginning and diminishes as it progresses due to proactive planning and pertinent decision-taking [6]. Therefore, the focus of the proposal is on the worst high risks case scenario, i.e., at the beginning of the project.

In the following, we present a set of definitions for building a conceptual framework which enables the consideration of risks as a manifestation of uncertainties associated with components.

Definition 1: The nth-dimension Risk of Using a Component c, as part of a software solution s, or simply RUC, is a vector $\vec{r}_s^{\,c} = (r_1, r_2, ..., r_n)$ where $r_i \in [0,1] \subseteq \mathbb{R}$.

Definition 2: The nth-dimension risk-evaluation of a set of components $C = \{c_1, c_2, ..., c_m\}$ for a software solution s is denoted as the relationship $R_s^C \subseteq C \times [0,1]^m$:

$$R_s^C = \{(c_1, \vec{r}_s^{\,c_1}), (c_2, \vec{r}_s^{\,c_2}), ..., (c_m, \vec{r}_s^{\,c_m})\} \tag{1}$$

where the second element $\vec{r}_s^{\,c_i}$ is the nth dimension RUC corresponding to the component c_i in the software solution s.

Definition 3: A risk-based prioritization function over a set of components $C = \{c_1, c_2, ..., c_m\}$ is a function $\rho : [0,1]^n \longrightarrow [0,1] \subseteq \mathbb{R}$. The resulting value of $\rho(\vec{r}_s^{\,c_i})$ will be called the total risk of a the component c_i under ρ.

Definition 4: The functionality of a software component respecting the set of requirements $Req = \{r_1, r_2, ..., r_F\}$ is a vector $\vec{f}^{\,c}_{Req} = (f_1, f_2, ..., f_k)$ where $f_i \in \{0,1\}$. It will be said that the component c accomplishes the functionality f_i iff $f_i = 1$. In contrast, it will be said that the component c does not accomplish the functionality f_i iff $f_i = 0$.

Definition 5: The functionalities of two components c_1 and c_2 respecting the set of requirements $Req = \{r_1, r_2, ..., r_F\}$ are the same iff $\vec{f}^{\,c_1}_{Req} = \vec{f}^{\,c_2}_{Req}$ and it will be said that c_1 and c_2 have different functionality iff $\vec{f}^{\,c_1}_{Req} \neq \vec{f}^{\,c_2}_{Req}$.

Definition 6: Given two components c_1 and c_2, the set of requirements $Req = \{r_1, r_2, ..., r_F\}$, the functionality of c_1 as $\vec{f}^{\,c_1}_{Req} = (f_1, f_2, ..., f_m)$ and the functionality of c_2 as $\vec{f}^{\,c_1}_{Req} = (g_1, g_2, ..., g_m)$, then it will be said that c_1 has less or equal functionality than c_2, denoted as $\vec{f}^{\,c_1}_{Req} \preceq \vec{f}^{\,c_2}_{Req}$ iff $f_k \leq g_k \forall k$.

Lemma 1: Given a set of components C, the binary relation $\preceq$ for functionalities of components imposes a partial order on C. Therefore, C is posed under $\preceq$.

Definition 7: The functional impact of a RUC $\vec{r}^{\,c}$ is a function $\lambda : [0,1]^n \longrightarrow \{0,1\}^k$. The resulting value $\lambda(\vec{r}^{\,c})$ will be called the loss of functionality of $\vec{r}^{\,c}$. It will be said that there is no loss of functionality iff: $\lambda(\vec{r}^{\,c}) = \vec{f}^{\,c}$ and it will be said that there is a total loss of functionality iff $\lambda(\vec{r}^{\,c}) = \vec{0}$.

Definition 8: Given a component c, its RUC $\vec{r}^{\,c}$, its corresponding evaluation of its loss of functionality $\lambda(\vec{r}^{\,c})$ and ρ a risk-based prioritization function, then the probability of occurrence of that loss of functionality will be $\rho(\vec{r}^{\,c})\lambda(\vec{r}^{\,c})$.

Definition 9: A risk-appraised situation for a component selection stage, as part of a component-based software process for developing the software s, is a quintuple $A_s = \langle C, Req, Rsk, \rho, \lambda \rangle$, where, C is a non empty set of components, Req is a non empty set of requirements, Rsk is a particular nth-dimension risk-evaluation R_s^C, ρ is a risk-based prioritization function over C, and λ is a functional impact function applicable to risks in R_s^C.

Definition 10: A risk-appraised situation for a component selection stage, as part of a component-based software process $A_s = \langle C, Req, Rsk, \rho, \lambda \rangle$, is called coherent iff

$$\vec{f}^{\,c_i}_{Req} \preceq \vec{f}^{\,c_j}_{Req} \Rightarrow \rho(\vec{r}_s^{\,c_i}) \leq \rho(\vec{r}_s^{\,c_j}) \quad \forall c_i, c_j \in C, \tag{2}$$

When this constraint is not satisfied, then it is called an incoherent risk-appraised situation.

Lemma 2: Any risk-appraised situation $A_s = \langle C, Req, Rsk, \rho, \lambda \rangle$, having just one element in C, is coherent.

The proof is trivial because there is only one element in C and ρ is a function. Therefore, the total risk of the component c_i is equal to itself.

Definition 11: A set of components D is called disposable by risk of a risk-appraised situation $A'_s = \langle C \cup D, Req, Rsk, \rho, \lambda \rangle$ iff A'_s is incoherent, $A_s = \langle C, Req, Rsk, \rho, \lambda \rangle$ is coherent and both situations accomplish the condition of equal functionality, i.e.,

$$\bigcup_{c_i \in C} \vec{f}^{\,c_i}_{Req} = \bigcup_{c_k \in C \cup D} \vec{f}^{\,c_k}_{Req} \tag{3}$$

Lemma 3: Given an incoherent risk-appraised situation $A_s = \langle C, Req, Rsk, \rho, \lambda \rangle$ then, by definition

$$\exists c_i, c_d \in C \vec{f}^{\,c_d}_{Req} \prec \vec{f}^{\,c_i}_{Req} \tag{4}$$

and

$$\rho(\vec{r}^{\,c_d}) \geq \rho(\vec{r}^{\,c_d}) \tag{5}$$

then $\{c_d\}$ is disposable-by-risk of A_s.

Lemma 4: Given a coherent risk-appraised situation $A_s = \langle C, Req, Rsk, \rho, \lambda \rangle$ and $\exists c_i, c_d \in C$

$$\vec{f}^{\,c_d}_{Req} \prec \vec{f}^{\,c_i}_{Req} \tag{6}$$

and

$$\rho(\vec{r}^{\,c_d}) \geq \rho(\vec{r}^{\,c_i}) \tag{7}$$

then $\{c_d\}$ is disposable-by-risk of A_s.

IV. The Araucanía Digital Smart-city Example

In order to illustrate our proposal, we present an example using the Araucanía Digital Smart-city Project (ADSP) context, that includes air pollution forecasting functionality. The ADSP goal is to develop smart cities systems in the region of La Araucana, Chile. The project is funded by the Inter-American Development Bank (BID) and is executed by industry and academy actors [39].

First, we define our risk vector, following Definition 1, that considers the risk associated with intelligent components and with traditional software development projects (we present a scenario with already evaluated risks, and thus, we do not review how the values were generated). The risks for the intelligent components are those already identified in Section II: (1) Experiment Management (EM), $p = 0.05$; (2) Difficulties to Estimate Results (DER), $p = 0.1$; (3) Development Team (DT), $p = 0.15$; (4) Glue Code (GC), $p = 0.15$; and (5) Data Workflows (DW), $p = 0.05$. We also include the following 2 risks related to traditional software development: (6) Budget Limitations (BL), $p = 0.15$; and (7) Timeline Restriction (TR), $p = 0.15$ [40].

Second, we define a set of software components that provide air pollution forecasting functionality. Each component considers an associated algorithm previously used in another context for this purpose [41]. We name every component based on the associated algorithm-name as follows: (1) Support Vector Machine (SVM); (2) Artificial Neural Networks (ANN); (3) K-Means (KM); (4) K-Nearest Neighbors (KNN); and (5) Regression Models (RM).

Third, we present a resume of the seven risks evaluation related to the five intelligent software components (all mentioned above) (Table IV). Also, we set the values according to the context that the software development team and the project give us (we stand that we do not consider the methodology to calculate the risk value, and thus, we assume that this example does not represent a case study with appropriate empirical rigour). Here, the team is one project manager, two senior software developers, one junior data analyst, and one senior software engineering scientist. It is crucial to notice that we do not have a machine learning specialist in our team (this context represents a particular case that may change with a different team or a different project).

TABLE IV. RISK EVALUATION OF AN INTELLIGENT COMPONENTS SET

R_s^C	EM	DER	DT	GC	DW	BL	TR	ρ
SVM	0.5	0.5	0.6	0.5	0.6	0.5	0.4	0.41
ANN	0.4	0.6	0.6	0.5	0.8	0.6	0.6	0.47
KM	0.3	0.4	0.4	0.5	0.6	0.4	0.3	0.47
KNN	0.3	0.4	0.4	0.6	0.6	0.4	0.3	0.34
RM	0.2	0.2	0.2	0.6	0.6	0.3	0.1	0.24

In order to evaluate how many software requirements accomplish the functionalities of a set of software components, we present a resume in Table V. The collection of software requirements is defined as follows [26]: (1) Air Pollution Index Forecasting (APF), i.e., the prediction of the future value of the polluting particle; (2) Interpolation of the Current Pollution value (ICP), i.e., constructing new data points within some geographical areas; (3) Automatic Fail Identification (AFI), i.e., automatic identification of "not a number"(NaNs) values or infinities appearing in the model during the execution of the system; (4) Editable Model (EM), that is, the component supports hyper-parameters updating; and (5) Stale Model Aware (SMA), that is, the model allows an automatic stale identification.

In Table VI, we present the loss of functionality of components due to the risks mentioned above. To do this, we use the λ function on each functionality defined in the previous step.

Following the definitions, we have a risk-appraised situation as we describe in Definition 9. Additionally, there exists an incoherent risk-appraised scenario because, for example, SVM provides less functionality than RM, and its risk is higher than RM. Therefore, SVM is risk disposable. Similarly, KNN offers better functionality than KM, and its risk is lower than the risk of KM. Therefore, KM is risk disposable too. Removing the disposable components, we have the following situation that $\preceq$ imposes to the component set:

TABLE V. THE FUNCTIONALITY OF AN INTELLIGENT SOFTWARE COMPONENT WITH RESPECT TO A SET OF REQUIREMENTS

$\vec{f}^{\,c}_{Req}$	APF	CCD	AFI	EM	SMA	ρ
SVM	1	0	0	0	0	0.41
ANN	1	1	1	1	0	0.47
KM	0	1	0	1	0	0.47
KNN	1	1	0	1	0	0.34
RM	1	1	1	0	0	0.24

TABLE VI. LOSS OF FUNCTIONALITY OF COMPONENTS

λ	$\lambda(APF)$	$\lambda(CCD)$	$\lambda(AFI)$	$\lambda(EM)$	$\lambda(SMA)$	ρ
SVM	1	0	0	0	0	0.41
ANN	1	1	1	1	1	0.47
KM	0	1	0	1	0	0.47
KNN	1	1	0	1	0	0.34
RM	1	1	0	0	0	0.24

$$\vec{f}^{\,RM}_{Req} \preceq \vec{f}^{\,ANN}_{Req}; \vec{f}^{\,KNN}_{Req} \preceq \vec{f}^{\,ANN}_{Req} \tag{8}$$

Finally, we selected these three components for the forecasting functionalities (RM, KNN, ANN). The potential loss of functionality due to risks, by using the logic operator "AND", gives us additional security on functionality AFI. To select a sequence, we first select the less risky component to ensure some functionality on early releases. But, due to the team size, we may support only prototype development at the moment. Therefore, we first plan RM and KNN then ANN. Note that risks are going down from 0.47 to 0.24*0.34*0.47.

V. CONCLUSION

In this paper, we have presented a solution proposal to the problem of intelligent software component selection. First, we have conducted a systematic literature review that allows us to identify a collection of risks that we classified into three main categories: (1) Development; (2) Evolution; and (3) Project Management. This review differs from previous related ones because our goal has been found lack of software engineering, instead of identifying a specific way to deploy intelligent systems. Second, we have formalized our proposal by presenting a conceptual framework and risk reduction strategy to support the component selection process. To the best of our knowledge, there is no work addressing the selection problem in the way that we have been presenting it. Third, we present the scenario of risks and how to select more than one component instead of just the best one. In this way, the advantage of this proposal is that it allows looking for not only the optimal option but a set of available best ones. Fourth, we have illustrated this scenario with a case of software planning in the context of an air pollution forecasting functionality as part of a Smart-city project. Fifth, as a limitation, while we considered that our presented example illustrates our proposal, under no circumstances we pretend to present this as a case study or an empirical evaluation. Thus, our future work is: (1) update our systematic literature review; (2) improve the proposal by formulating the component selection problem as a search based problem. With this approach, we expect to prove the methodological framework supporting our idea; and (3) conduct a study case, using the frame of The Araucanía Digital Smart-city Project.

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A Strategy for Drone Traffic Planning

Dynamic Flight-paths for Drones in Smart Cities

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***Abstract*—This paper presents a solution for creating dynamic flight plans for drones. The number of drones is expected to increase dramatically, and there will be a demand for drone traffic planning solutions. The approach used here is based on a multidimensional grid with fixed top-level paths and lower-level paths used for local traffic between the departure and arrival points and the top-level paths. Flight plans may change dynamically if disruptions happen. The proposed solution includes the establishment of temporary no-fly zones and priority traffic.**

Keywords-unmanned aerial vehicles; drones; flight planning; smart cities; routing algorithms; scheduling algorithms.

I. INTRODUCTION

"Smart cities" is a concept that uses information and communication technology to improve the quality of life for its citizens by delivering better services, reducing environmental footprint and improving citizen participation. One aspect of smart cities is to make transport smarter [1]. This paper focuses on how to meet the challenges of drone traffic for delivery and other applications.

Some of the leading information and communication technology companies (Google and Amazon) are currently exploring new delivery services using unmanned aerial vehicles (drones). Drone technology has also attracted the attention of traditional logistics companies like DHL, UPS and Deutsche Post AG, as well as big retailers like Walmart.

Drones are becoming increasingly important in agriculture, medical sector, civil engineering, insurance, security, and energy. According to Goldman Sachs, the future drone market is predicted to be $100 billion by the year 2020 [2] where the defense sector remains the largest consumer with around 70%. However, Business Insider Intelligence researchers are less optimistic and expect sales of drones to surpass $12 billion in 2021 [3]. The lift capacity and operating distance are improving, mainly due to advances in battery technology.

Drones are particularly of great interest for last mile delivery applications in smart cities. Last mile delivery is the end part of the delivery chain, which deals with the distribution of goods from long haul to the end user, being the most expensive part of the delivery chain. As part of the upcoming Industry 4.0 revolution, the autonomy of drones plays an essential role in the evolution of logistics. Drones are becoming commonly used in the early stages of logistics (commonly called first-mile) as well as in its last stages.

Intralogistics operations deal with the optimization, integration, automatization, and management of data flow and goods inside a distribution center. Drones can be smartly used for transportation inside factories, spare parts delivery, goods storing and delivering.

Use of drones for city infrastructures surveillance is of great interest as they can be used for building inspections and maintenance.

In 2013, Amazon announced Prime Air [4], a service that utilizes multirotor drones to deliver packages from Amazon to customers. The German logistics company Deutsche Post DHL started its Parcelcopter project in 2014. One application of the Parcelcopter [5] has been to transport medicine to the German island of Juist in the North Sea.

Google revealed Project Wing [6] in 2014 to produce drones that can deliver larger items than Prime Air and Parcelcopter. Recently, in April 2019, Project Wing has received regulatory approval to start making last-mile commercial drone deliveries in Australia, according to the American technology news channel - The Verge [7].

In 2014, the US company PINC launched the PINC Air service, using its drones to follow goods in transports, vehicles and more. These drones are equipped with cameras, Radio-Frequency Identification (RFID) and barcode readers, and have software for real-time 3D mapping, navigation, goods identification and localization [8].

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In 2014, the United Arab Emirates announced its plan to use drones to distribute official government documents such as permits and identification cards [9].

A startup company, Matternet has partnered with Swiss Post to test a lightweight package delivery drone [10].

Recently, the UNICEF Innovation labs [11] explored the use of drones for search and rescue operations. The drones could be useful in emergency situations, such as rescuing victims of natural disasters (floods, extreme temperature events, earthquakes, mudslides, storms and wildfires) when roads are no longer usable. Drones may be used to transport life-saving materials in both humanitarian and development contexts [12]. Deliveries of emergency medical supplies and kits can reduce the response time in multiple humanitarian contexts that require the provision of life-saving immunization materials, biological samples, transfusion plasma or organs. UNICEF has used drones for such operation in African countries and Vanuatu isle in the Pacific Ocean [13].

A kidney scheduled for transplant was delivered by a drone for the first time on April 19th, 2019, in Baltimore, United States [14]. A specially tailored drone having the size of a washing machine carried a healthy human kidney to hospital. The doctors successfully transplanted the organ. The operation took place at night, and the drone traveled 4.5 km in 10 minutes. The whole operation was the result of a three-year collaboration of a team of doctors, researchers, engineers and plane experts who worked together at the Maryland Medical Center and the Living Legacy Foundation. The transport of transplant organs using the drones reduces costs, reduces transport time and improves the quality of medical services. Conventional transport methods, including the use of cars, helicopters and planes, have significant drawbacks: airplanes are too expensive, commercial flights take too long, and small aircraft are dangerous to medical teams.

The increase in drone traffic calls for a traffic management system to make sure that drones operate in a regulated environment to avoid collisions and improve the safety of drone operations. The aim of this paper is to present an idea for how drone flight management can be implemented in urban areas.

The rest of the paper is organized as follows: The next section addresses some current challenges related to the commercial use of drones. Section III provides an overview of related work. Section IV discusses drone flight planning. Section V presents an idea for an algorithm. Section VI concludes and provides ideas for further research.

II. CURRENT CHALLENGES

The use of drones for professional purposes introduces a set of challenges that must be observed and addressed:

- Most drones use electrical motors. The battery capacity is proportional to the weight of the battery. The capacity of the batteries becomes a limiting factor in how far a drone can travel before needing to be recharged. Battery technology is improving and will increase both travel distance and payload weight.
- Flying distance and payload weight depends on battery capacity. A larger battery will increase flying distance, but also decrease the payload capacity. Balancing payload weight, battery weight, and flight time are important considerations when attempting to minimize the cost or the delivery time for drone deliveries [15].
- The flight planning for drones is a multi-objective optimization problem. The solution needs to take into account the existence of no-fly zones and dedicated paths for drones to follow.
- Drones may be difficult to maneuver in tight spaces.
- Scalability: How does a fleet of drivable drones might be organized so that they do not crash into one another implemented in the complex reality of real city streets and the surrounding airspace. This calls for implementation of traffic planning and collision avoidance systems as more and more drones enter the airspace.
- Algorithmic path-planning taking into account of urban-like landscape with buildings, roads, parking areas, landing pads and no-fly zones.
- Since the law regarding the use of drones is still not fully developed, other challenges or restrictions are currently being regulated by the European Union [16], e.g., drone weight, maximum possible flying altitude, no-fly zones over "crowds", minimum safe distance, etc.

III. RELATED WORK

Mok [17] presents the prototypes of drones developed at MIT´s Computer Science and Artificial Intelligence Laboratory (CSAIL), located in Cambridge, Massachusetts, USA. These drones, equipped with wheels, represent a mix between a drone and a tiny car that can not only fly but are capable of driving on the ground, making a tradeoff related to energy consumption and speed (time of delivery). Their tests included eight drones deployed at the same time and following autonomously their own path revealed the machines could fly for 90 meters or drive for 252 meters before needing to recharge their batteries, a relatively short distance.

Schermer et al. [18] used a heuristic algorithm to extend the original Vehicle Routing Problem (VRP) [18] to the Vehicle Routing Problem with Drones (VRPD), where a drone works in tandem with a vehicle to reduce delivery times. The authors emphasize qualitative differences between trucks and drones and highlight the usefulness of incorporating drones in last-mile logistics.

The limitations of existing VRP solutions applied for planning drone deliveries are illustrated by Dorling, Heinrichs, Messier and Magierowski [15]: multiple trips to the depot are not permitted leading to solutions with excess drones, or the effect of battery and payload weight on energy consumption is not considered, leading to costly or infeasible routes. The authors solve drone delivery problems with a Multi-Trip VRP (MTVRP) that compensates for each drone's limited carrying capacity by reusing drones when possible. The authors used a model based on the approximately linear relationship between power consumption and battery and payload weight. The main drawback of their solution is their local optimization algorithm based on simulated annealing and not a global optimization algorithm. Furthermore, the authors also admit that the simulated annealing algorithm does not take advantage of characteristics inherent to a VRP such as it does not use geographical information to reduce the likelihood of trying infeasible routes between two locations at opposite ends of the area of operations.

The researchers from MIT [20], using extra hardware (video camera and processing power for image recognition) developed an obstacle-detection system that allows autonomous drones to zip through trees at 48 km/h in different delivery scenarios.

The UTM (Unmanned Aircraft Systems Traffic Management) project [21] enters in the fourth stage where NASA will test drone traffic management systems in six field test sites of U.S. cities – Alaska, Nevada, Texas, North Dakota, Virginia, and New York. The project aims developing technologies, responsibilities and procedures for safely managing the airspace that includes autonomous aircraft operations in populated areas. Structured in four levels entitled technical capabilities, and focused first on agriculture, firefighting and infrastructure monitoring, the operators of drones are enabled to set flight plans reserving airspace for their operations and provide situational awareness about other operations planned in the area. The second stage explores the space beyond visual line of sight of the operator in sparsely populated areas and contingency management. The third involves tracking capabilities of drone operations over moderately populated areas. Perhaps the most complex, the fourth stage, aims to extend the operations defined in the third stage by sending correspondence and delivering packages in high populated areas. Also, testing the technologies that could be used to manage large-scale contingencies aims this last stage.

Dukowitz [22] revealed other important Urban Aerial Mobility (UAM) projects supported by more than 500 European stakeholders and by European Commission funds that intend to bring urban mobility to the third dimension bridging the Unmanned Traffic Management with Urban Traffic Management. The goal of such projects is to develop a cloud-based software platform to integrate low-flying unmanned aircraft systems into the airspace safely.

Since scientific literature is mostly limited to the physical implementation of the flying devices and to the control methods, not to the integrated solutions, maybe the most useful and with open content related work from software point of view, about algorithms and information management systems focused on drone traffic management systems is represented by Plaza [21]. The author creates an elaborated model of the system of information for the traffic management of unmanned aircraft systems composed by Users (the human components clustered on 10 groups depending on their role), Functions (22 information management activities according to the temporality of the flight / mission), Datasets (managed data sorted into groups by the content and the temporal validity in order the conformability and the orderliness) and 2 Functional subsystems (Technical infrastructure elements and Operational support systems). The model is implemented like an information structural matrix, which systematically contains the managed data handled by the users connected to the execution of the functions. The activities described are related only to civil operations, not military, which must follow other rules. Besides collecting data covering UAV position and movement data, UAV status data, UAV type related data (static data), mission-related flight plan data, the author also considers environment-related data, which is relevant for the safe operations. Operation of the information structural model provides comprehensive data sharing among the industrial partners, deliverables companies, user communities, about the UAVs and their operations. Another merit of [23] is that it provides a clear separation of notions like UAV (Unmanned Aerial Vehicles), which is the flying object (technical parts), and the UAS (Unmanned Aircraft Systems), which is a greater technical solution, that includes the UAV plus the sum of the control infrastructure (the human operator).

These related works do not handle the increasing number of drones and the need for traffic planning, including the dynamic establishment of no-fly zones and noise reduction. Our solution addresses these problems, but does not concern itself with battery time. We expect the development of battery technology to increase both distances traveled and lift capacity.

The solution is based on two well-known areas from computer science: scheduling and routing. To allocate time slots, a scheduling algorithm is used. The scheduling algorithm makes sure that the drone gets operating space throughout the flight. The routing algorithm calculates an efficient route through the airspace. Scheduling algorithms are heavily used in operating systems. Routing algorithms are found in both computer networks and the design of printed circuit boards and integrated circuits.

IV. DRONE FLIGHT PLANNING

An increase in drone traffic will require a traffic management system to control the airspace.

Land-based transport is basically handled by paths in a two-dimensional grid, but with possibilities to make intersections multi-level to avoid roundabouts or single-level intersections. The infrastructure for land-based transport is expensive and inflexible. A road or a train line normally has a life-span of hundreds of years.

A. *A layered model of the airspace*

The difference between land-based transport and air-based transport is that paths may be established in three dimensions since it is possible to divide the airspace into several horizontal layers. This is already done for conventional air transport. Drones will use the airspace below that used by conventional air transport. Another advantage is that airspace is not fixed. The paths may be dynamically established and removed based on needs.

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Fixed high-level path 1
Fixed high-level path 2
Endpoint layer 1
Endpoint layer 2
Endpoint layer 3

Figure 1. Layer design

The dynamic flight planning system presented here is using five levels (Figure 1), but the number of levels can be increased if necessary. On the upper levels, a number of fixed paths are established. These will be the "highways" for the drone traffic. When the drone needs to go from a location to the highway entry point or from the highway exit point to a specific location, separate paths will be established on endpoint layers 1, 2 or 3. The algorithm will start with endpoint level 1, and check for conflicts. If a conflict is detected, it will move on to endpoint layer 2, and so on. These paths are allocated dynamically. The algorithm proposed for channel routing is based on a multi-layer algorithm for printed circuit board design. The modification is to make it dynamic. A set of fixed channels is established. Then, from the nearest point in an existing channel, the dynamic path is established from the source to the destination.

The rationale for using fixed upper levels ("drone highways") is considerations about noise. This is important for urban areas, where the main corridors for drone traffic may be located away from noise sensitive areas.

B. *The algorithm*

Figure 2 shows the establishment of the flight path from the point of departure (S) to the point of arrival (E). The yellow path shows a part of fixed high-level path ("drone highway"). The orange paths show the path from the point of departure (S) to the entry point of the fixed path, and from the exit point of the fixed path to the point of arrival (E). The algorithm will include the following steps:

1. Based on departure location, find the nearest entry point to the higher-level fixed path ("drone highway")
2. Based on arrival location, find the nearest exit point from the higher-level path ("drone highway")
3. Calculate distance and air time between departure point and entry point
4. Calculate distance and air time between the exit point and the arrival point
5. Search for next available slot time taking distance to the higher-level path into consideration
6. Reserve slot time
7. Check for collisions in the departure area, if collision move to next endpoint layer
8. Check for collisions in the arrival area, if collision move to next endpoint layer
9. Submit flight plan

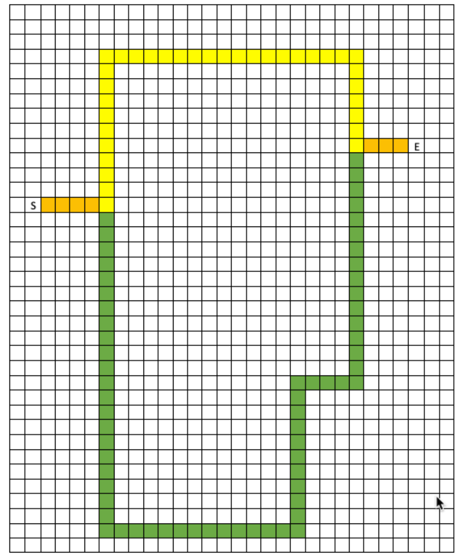

Figure 2. Submitted flight plan

A more formalized version of the algorithm using a single higher-level path ("drone highway") is shown in Figure 3.

```
Input:
HWay_ID, DR_ID_, DR_ID_Velocity,
Start_Loc, Arrival_loc;  Entry_SET, Exit_SET;
Output:
DR_ID_Flight_Plan ;
Start:
Chosen_HWay_Entrance :
   If  ( ∀ HWay_Entrance  ∊ Entry_SET )
     Dist (Start_Loc, Chosen_HWay_Entrance)   ≤
     Dist(Start_Loc, HWay_Entrance) ,
Chosen_HWay_Exit  :
   If ( ∀ HWay_Exit  ∊ Exit_SET )
     Dist (Arrival_Loc, Chosen_HWay-Exit)   ≤
     Dist(Arrival_Loc, HWay_Exit) ,
  Calculate Time (Start_Loc,  Chosen_HWay_Entrance);
  Calculate Time ( Arrival_Loc,Chosen_HWay_Exit) ;
  Assign Slot_Time;
  Return( Drone_ID_Flight_Plan);
End
```

Figure 3. Single-level path flight planning

At the scheduled time, the drone will take off and follow the calculated path to its destination. Figure 4 shows how multiple fixed paths can coexist. In this case, the paths will be on different levels, with intersections where drones can shift from one fixed path to another. This increases the complexity of the algorithm, since slot times for each path must be taken care of. The green fixed path is on one of the upper levels, the two blue paths are on another upper level. The drones will shift from one level to another at the interchanges (grey color).

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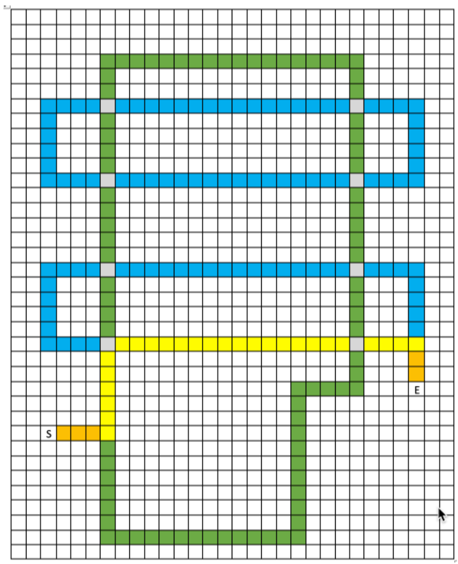

Figure 4. Multiple fixed paths on the upper levels

The enhanced algorithm is shown in Figure 5.

```
Input:
HWay_ID[I], DR_ID[J]_, DR_ID[J]_Velocity,
I ∈ {1…….K} /* number of highways */
J ∈ {1……..M} /* number of drones */
Start_Loc[J], Arrival_loc[J];  Entry_SET[I], Exit_SET[I];
Departure_Collision[J] = False;
Arrival _Collision[J] = False ;
Output:
Flight plan for all drones;
Start:
Stop = False;
While (Not  Stop) {
  For all drones: J: 1 to M:
    Chosen_HWay_Entrance [J] :
      If  ( ∀ HWay_Entrance [I] ∈ Entry_SET[I] )
        Dist(Start_Loc[J], Chosen_HWay_Entrance[J]) ≤
        Dist(Start_Loc[J], HWay_Entrance[I]) ,
    Chosen_HWay_Exit [J] :
      If ( ∀ HWay_Exit [I] ∈ Exit_SET[I] )
        Dist (Arrival_Loc[J], Chosen_HWay-Exit[J])   ≤
        Dist(Arrival_Loc[J], HWay_Exit[I]) ,
    Calculate Time [J] (Start_Loc[J],
Chosen_HWay_Entrance[J]);
    Calculate Time [J] ( Arrival_Loc[J],Chosen_HWay_Exit[J]) ;
    Assign Slot_Time[J];
  If ( ∀ x ∈ {1…..M} , Departure-Collision[x] = False and
    Arrival_Collision[x] = False)
    Stop = True;
  Else
    If ( ∀ x ∈ {1…..M} , Departure-Collision[x] = True OR
      Arrival_Collision[x] = True)
       Remove collision by moving to next endpoint layer ;
       Stop = True;
}
Return( Drone_ID_Flight_Plan[J]);
End;
```

Figure 5. Multiple level paths flight planning

C. Disruptions

Disruptions may happen. In particular, disruptions may be caused by the establishment of temporary no-fly zones. This can be above areas that either represents a danger for people on the ground, like large gatherings, or accidents where drone traffic could disrupt emergency service operations.

Disruptions may also be caused by priority traffic, e.g., for delivering a heart defibrillator.

If drones have communication capabilities, it is possible to upload new flight instructions if something happens. Figure 6 shows the establishment of a no-fly zone marked in red. The top-level path needs to be reconfigured.

In this case, it is possible to change the path to not conflict with the no-fly zone. The distance will be one grid unit larger, so original slots can be reused.

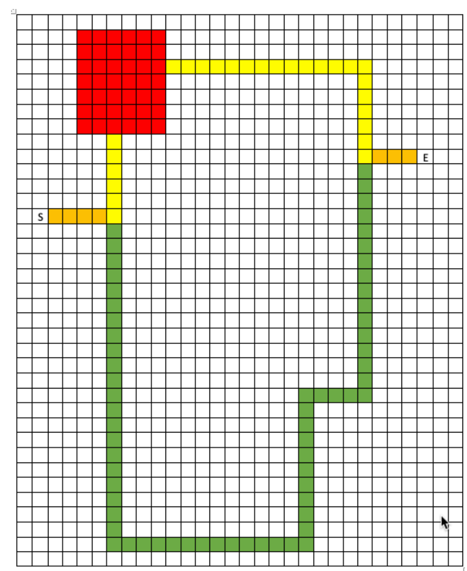

Figure 6. Temporary no-fly zone established

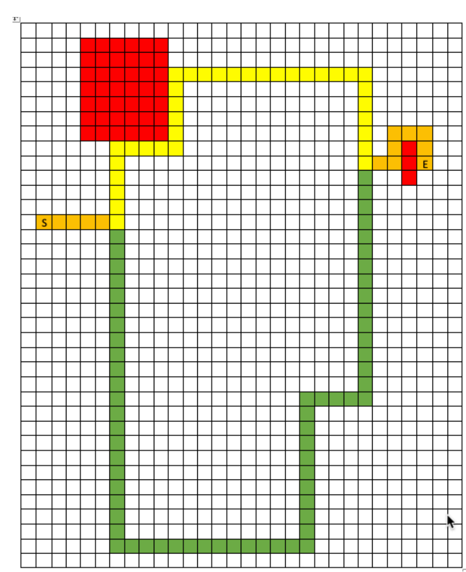

Figure 7. Dynamic rerouting

Figure 7 shows the reconfigured high-level path, and also introduces a no-fly zone close to the arrival point. The last stretch is recalculated to not interfere with the no-fly zone.

Since drones always have a limitation on flying distance, it is necessary to plan for situations where the drone will run out of battery before accomplishing its mission, e.g., due to the establishment of no-fly zones or priority traffic. The problem can be solved by establishing some locations where drones can land and later be picked up by the operator.

V. Conclusions and Future Work

As drone lift capacity is growing and travel distance increases, drones will be used for commercial purposes. Drone traffic, especially in cities, will increase dramatically. This calls for a drone traffic management solution to keep the air space safe. In this paper, we have shown one possible solution to drone traffic management using multiple layers where some layers contain fixed paths ("drone highways") and other layers are used for traffic from departure points to the highways and from the highways to the arrival point. A flight plan is submitted before the flight, and the system will find the best possible schedule.

However, an important issue regarding drones refers to governing laws of flying. According to [24], every country has specific laws. Thus, our algorithm would not be applied in regions like the State of Alabama, USA, where a city ordinance ban flight over city properties, parks and recreational areas or any other area specified by the police.

Future research includes developing a simulator for the flight scheduling system. The simulator should allow for a large number of submitted flight plans in order to prove the concept. The simulator should have a visualization module to show drones moving in the airspace.

Since, as far as we know, no fully functional and available UTM solution is known, the business model and operating methods of the system are not known at present. Future research should find answers to these questions and address the development of such measures. In this sense we will also include developing a business model for the flight planning system.

Blockchain is an immutable distributed ledger. Cryptographic techniques make sure that it is not possible to change the content of an entry when it is put on the blockchain. All entries are recorded in blocks that are distributed to many computers. If one or more computers fail, the data is still obtainable from the network. If there should be an inconstancy, the majority will win. Essentially, blockchain makes it possible to do transactions without an intermediary. Since a traffic planning system will handle many different actors, the use of blockchain technology and smart contracts may be explored as a possible repository for flight plans.

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Citizen Participation through Digital Platforms: the Challenging Question of Data Processing for Cities

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***Abstract*—This paper focuses on digital platforms supporting citizen participation in the era of Smart Cities. Our study presents and analyses two examples of online participation platforms, implemented by two Walloon cities: Mons and Liège (Belgium). These two cases highlight the differences and the similarities between both cities' interpretation of digital participation, as well as the difficulties they faced, especially considering the data processing by city officials. In light of the challenges observed through those two cases, we suggest that digital platforms might potentially be misused, and somehow bias the whole digital participatory process. We therefore issue recommendations about how to design, launch and manage such platforms and, moreover, suggest that platforms should be supplemented by other digital or traditional participatory processes in order to reach higher levels of participation.**

Keywords-citizen participation; digital platform; data processing; Smart City; Belgium.

I. INTRODUCTION

Facing demographic and environmental issues [1], many cities worldwide are looking for a new urban ideal and are moving towards a development strategy based on the Smart City concepts [2]. This "smart" phenomenon gives rise to citizens' participation, which is a crucial dimension to ensure social sustainability of Smart Cities [3]. Cities consequently face the challenge of organizing such participation as efficiently as possible, which in turn leads to the proliferation of digital platforms for citizen participation. This research aims at studying those popular digital platforms, through the analysis and the comparison of two platforms implemented in two Belgian cities, namely Mons and Liège. How are such digital platforms administered and exploited? What are the assets and the limits of those platforms? How could such digital participatory process be enhanced?

This paper is structured in four additional sections. Section II provides a short literature review about the emergence of citizen participation as a key aspect of the Smart City and summarizes new interpretations of participatory processes in the digital era, including digital platforms. Section III then gives a global overview of both Walloon platforms, while Section IV delves into the results of the two initiatives. Our methodology is briefly mentioned in Subsection A, followed by our analysis of both platforms regarding the topics (Subsection B), the "likes" (Subsection C) and the priority actions (Subsection D) as implemented by one of the two cities. Finally, Section V focuses on the main limits of both digital platforms and provides recommendations to improve such participatory process.

II. STATE OF THE ART

Citizen participation has always been an important part of urban governance, this concept being inextricably and intrinsically linked to the very essence of democracy [4]. Participation of the civic society is therefore much older than would appear at first sight, considering that the appeal for participatory action dates back to the events of May 1968 [5]. Since then, recurrent limits (regarding "true" participation) have been continuously reported in the state of the art, and among them tokenism has been considered as one of the main risks for participation, i.e., symbolically hearing the citizens' voice rather than concretely taking their comments into account or giving them real decision power [6]. Over the past 50 years, the public participation has grown in popularity and citizens are nowadays more and more empowered to take part in decision-making processes in their city, especially regarding current issues, such as environmental and technological developments [7]. Whilst designers and architects integrate their users' needs and ideas through co-design processes [8], policy makers gradually realize the importance of involving residents in participatory processes in order to collect their citizen expertise, i.e., an intertwined body of knowledge built on their past experiences, local perceptions and field understanding [9].

In the Smart City context, this collective intelligence is now recognized as the main source of smartness, ex-aequo with digital technologies [1]. Until recently, Smart Cities lacked citizen perspective and were essentially focused on the introduction of new technologies [10][11]. This technocentric approach has the disadvantage to impose solutions to the city users, without knowing if those users really want or need them, and thus without ensuring that they will eventually use them [3]. Consequently, citizens have recently been more and more considered as key stakeholders regarding the overall success or failure of the Smart City, since they can choose to accept or reject smart solutions and technologies [10]. The sustainability of the global smart model thus relies on the active involvement of the residents, through citizen participation and co-design processes [3].

Considering the current digital era, enthusiasm for participation has been growing higher than ever and several tools have been developed to collect citizens' point of view. Along with traditional methods (e.g., surveys, panel discussions, advisory boards, workshops, etc.), new forms of digital participation have consequently emerged in the Smart City context. Based on Arnstein's eight-level ladder of citizen participation [6], Douay proposes a classification of those emerging digital participatory processes according to citizens' decision power (see Table 1 below) [12]. This renewed ladder of participation shows that, according to this author, the digital era has not changed the types and levels of participation, but rather offers new and dematerialized tools to achieve them. According to the literature, Douay's model could be complemented by several other examples of digital participatory modes. For instance, sensors and wearables collect information from a large number of people, sometimes unwittingly, and the aggregated data reveals trends and patterns attesting to habits and lifestyles [13]. In the same vein, big data can also be generated from smartphone applications through which citizens can share real-time, geolocated information with the community and the municipality [14]. Additionally, one has to observe that Douay's ladder does not yet include digital platforms for citizen participation. Often assimilated to online suggestion boxes, those platforms become a place to submit ideas for one's city and to vote for the ideas that should take precedence, according to the voters' points of view, and therefore be implemented through concrete projects or policies [1]. In that regard, those platforms enable active, bottom-up involvement of citizens.

TABLE I. LADDER OF PARTICIPATION ADAPTED TO DIGITAL PROCESSES [12]

	Participation type	Activities	Platform examples
Co-decision	Deliberation	Debates and votes	DemocracyOS
	Co-decision	Law or program design	Consultation on the bill for a digital Republic
Contribution	Co-design	Collaborative design of digitals platforms	Hackathons
	Partnership	Co-construction of programs and decision sharing	participatory budget
Civic dialogue	Consultation	Survey	Online votes
	Communication	Dialogue by message exchange	Chat, Hangout
Information	Information 2.0	Top-down communication with the possibility of commenting or reacting (like)	Social networks
	Information 1.0	Top-down information without the possibility of communication	Newsletter

In 2016, the French Digital Secretariat of State has developed a classification of "Civic Technology", based on the Knight Foundation [15] and adjusted to the French context. This classification is divided into "technology for democracy" or "Gov Tech", and "technology for civic engagement" or "Civic Tech". On the one hand, Gov Tech are top-down tools which aim to improve public services and democratic practices (e.g., public spaces reporting tools). Civic Tech, on the other hand, are bottom-up tools, aiming to improve civic engagement of citizens (e.g., participatory budgets). In this classification, platforms of citizen participation are located at the intersection of the two categories. They indeed meet cities' interest in collecting citizens' opinions in a convenient way, while encouraging citizens to get involved in the development of their city [16].

In the European context, these platforms seem to grow as the most popular form of digital participation as many cities use them to reach citizens' views and local concerns [17][18]. Wallonia is no exception: since 2017 cities such as Mons and Liège (among others) launched their first digital platforms for citizen participation. How were both processes organized? What were the results? Where do those platforms rank in the renewed ladder of citizen participation? Are these platforms used as Gov Tech and/or Civic Tech tools?

III. PRESENTATION OF THE STUDIED PLATFORMS

Respectively called "Demain, Mons" and "Réinventons Liège", the two Walloon initiatives appear similar in many ways, since both platforms are supplied by the same company, CitizenLab. However, they have been customized for each city, implemented independently, and several discrepancies are observed between the two processes. Table II presents a comparison of both platforms and emphasizes their commonalities and differences, often stemming from the choices of the municipality.

As far as the monitoring of the project is concerned, a major difference exists between the two cases. The city of Liège has published the results of the platform in November 2017, and it is not yet the case in Mons, since the project has been put on hold around municipal elections in October 2018. One has to observe that CitizenLab, the provider of the two platforms, did not offer data analysis services in 2017. Both cities received the data in Excel format and had to analyze it. This is a real challenge for cities not used to deal with big data, and might partly explain why Mons at the present time still experiences some difficulties in pursuing with concrete proposals.

IV. RESULTS

A. Methodology

We collected the ideas and votes of both platforms in Excel format. The city of Mons directly transmitted the data to us, but in order to protect citizens' personal data, they only sent us the content visible on the platform.

TABLE II. COMPARISON OF "DEMAIN MONS" AND "RÉINVENTONS LIÈGE".

Context	***City***	Mons 95 000 inhabitants	Liège 196 000 inhabitants
	Platform name	"Demain, Mons" = "Mons Tomorrow"	"Réinventons Liège" = "Let's reinvent Liège"
Timing	***Process***	One single phase: idea submission and vote at the same time	3 phases: (1) Idea submission (2) Vote (3) Analysis by the city and communication of the results
	Duration	9 months from May 2017 to January 2018	8.5 months from March to November 2017
Information	***Communi-cation***	- Municipal newspaper - 21 meetings between citizens and the municipal council, in different neighborhoods	- Municipal newspaper - 2 info sessions for the students of the University of Liège
	Inspiration	- weekly email with newly submitted ideas - 22 ideas submitted by the city	- 5 thematic conferences - 20 first ideas submitted by the city
	Updates	Reminder emails	Reminder emails, promotional videos and Facebook posts
Idea submission	***Participa-tory modes***	- online platform - paper form to send - 5 thematic workshops	- online platform - 5 workshops with neighborhood committees
	Number of topics	12 topics: multiple choices are allowed	5 (then 7) topics: only one topic per idea
	Number of ideas	909 ideas, including 113 via paper form put online by the city for vote	983 ideas
	Number of ideas' authors	286 online, unknown for paper form	353
Idea selection	***Number of votes***	9,960 votes 8,336 likes 1,624 dislikes	94,688 votes 84,130 likes 10,558 dislikes
	Results	No official analysis nor communication of results	77 priority actions

In Liège, we manually collected the data directly from the platform, but since November 2018 the city has made them available on its open data platform [19]. In both cities, we therefore received no access to the personal data of the contributors (age, living place, number of votes, etc.) nor the number or duration of citizens' connections and so on. As a result, our study focuses on the citizens' ideas and on the cities' data management and processing. More specifically, our research is not intended to be an exhaustive analysis of both platforms, but rather focuses on the challenges encountered by both cities in terms of data processing. In further research, our analysis should be complemented by a study of participants: profiles, representativeness, digital divide, pressure groups, etc.

In order to gain a better understanding of the challenges encountered through data processing, we conducted 3 semi-structured interviews: the first one with the Mons Smart City Manager, the second one with the Mons Communication Manager, and the third with the CitizenLab Director of Francophone Markets. In Liège, we were offered no opportunity to meet any of the city representatives despite our repeated solicitations. We also attended several presentations by CitizenLab during 2018, when they were developing a data analysis method with "Demain, Mons" as an example.

Moreover, in order to be able to conduct critical review of the data processing as managed by the cities, we made our own qualitative and quantitative analysis of the data. The first step of our data analysis consisted in reviewing the whole set of ideas in order to check the number of suggestions associated with each predefined topic. We also checked the consistency between the detailed description of those ideas and the topic chosen by the participants or the city. Beyond the number of ideas, we also studied the allocated number of likes and dislikes, as a supposed marker of popularity for the ideas. However, those figures reveal to be insufficient to get a global overview of the citizens' proposals, which content and keywords are also important. Therefore, we additionally conducted a more micro perspective analysis and developed a tree-like structure of the submitted ideas, which are organized by thematic clusters.

B. *Analysis of the predefined topics*

In Mons, when a citizen suggested an idea, he/she had to link it to one or more topics among the 12 predefined ones, namely: Mobility; Urbanism and heritage; Social cohesion; Culture and tourism; Sustainable development; Employment, economy and trade; Cleanliness; Security; Education and training; Sport and associative life; Local governance; Housing. In Liège, 5 topics were proposed to citizens during the ideas' submission phase: Energy transition; Social inclusion; Citizen participation; Collaborative practices and creative approaches; Digital revolution. We observe a difference between the two cities: the topics in Mons are more precise and focused on citizens' day-to-day lives whereas in Liège they are broader and more theoretical. These choices of topics reflect local political projects, and this way guide and may restrict citizens' proposals. Our analysis of the data reveals some ideas off topics but still relevant for the city. It shows that citizens use the platforms to express themselves, even though their ideas deviate from the topics chosen by the city.

In Mons, in order to process the collected data, the city decided to associate a unique topic to each proposal. The goal was, according to the interviewed city representatives, to avoid duplicates and to be able to transmit each idea to the aldermen and to the concerned technical services for an expert opinion. The possibility for citizens to choose several topics made this selection step complex, particularly because many proposals pointed to several subjects (e.g., "redevelop a green space and create a parking relay"). As we compare the multiple topics chosen by the citizens and the unique ones later defined by the city agents (see Figure 1), we observe that several topics appear popular (for instance "social cohesion" and "sustainable development")

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as they are retained for many proposals, but yet being the main subject for only 30% of the original ideas.

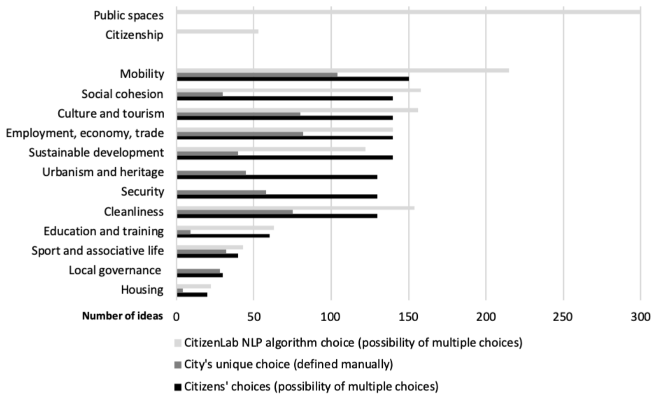

Figure 1. Topics comparison for “Demain, Mons”

We also compared these topics to those proposed by CitizenLab, the platform provider, obtained through their Natural Language Processing (NLP) algorithm. This algorithm analyses the content of the proposals, gathers similar ideas and extracts keywords. The operating details are a trade secret closely guarded by CitizenLab. Some of the main keywords highlighted by the algorithm are identical to the platform’s topics. But interestingly, the algorithm did not keep three topics (i.e., Security, Urbanism and heritage, Local governance) and created two (Public spaces and Citizenship). Yet, “Citizenship” appears only once in the 909 citizens’ text ideas, which are therefore somehow interpreted by the algorithm. Without transparency on the method or open source software, how to be sure that the results reflect citizen ideas? Moreover, the “Public spaces” topic includes the largest number of proposals according to the algorithm, ranking first in front of the “Mobility” topic that was #1 in citizen and city rankings. This is not surprising knowing that “Public spaces” is an inclusive notion concerning every city. Indeed, cycle paths, waste management or car parks can be linked to public spaces. The negative aspect of such a broad topic is its low operationality: it requires skills spread across many technical city services to be realized and it is redundant with topics such as mobility, security, cleanliness, etc. Thus, the predefined topics should remain as precise as possible, or at least correspond to the same level of detail in order to avoid overlaps between topics.

In Liège, of the process the city, has modified some predefined topics and reorganized the classification of citizens’ proposals. These successive changes are shown in Table 3. We observe that the topics were strongly modified after the ideas deposit phase. Three out of five topics have been merged (to become a single “Participative, collaborative and digital city” concept), while five completely new topics appeared, more focused on their terminology and urban-planning oriented. Moreover, the creation of the topic “unclassifiable” is a recognition of citizens proposals that fall outside any predefined scopes. However, none of these 57 “unclassifiable” ideas is part of the 77 priority actions to be carried out. Thus, the topics’ reorganization after the ideas generation phase and before the voting phase is a function of many parameters: citizen’ ideas of course, but also, and perhaps more surprisingly, general city policy.

Moreover, after the voting phase and before the presentation of the results, two topics were again modified without any impact on the ideas distribution. “Green spaces, greening, urban agriculture” has become “Greening and urban agriculture” and “Equip, plan and embellish the city” was modified into “Green, collective and peaceful areas”. From a technical point of view, one could wonder: how did “green spaces” change from one topic to another without impacting the ideas classification? And, from a semantic point of view: why choose to separate “green spaces” from “greening”, but to associate them with “collective” and “peaceful” spaces? Despite a greener coloration, the topic “Green, collective and peaceful areas” grows closer to the idea of “public space” put forward in Mons by CitizenLab’s NLP algorithm. As for Mons, we observe that this large topic lumps together a variety of sub-questions, which raises again the challenge of low operationality. In that regard, one would wonder why any city would want to bring out the issue of public (green, collective and peaceful) spaces as the main topic. We interpret this as a purely political choice.

To conclude, our study of the topics shows that the choice of topic title can create big variations in the obtained results. To promote objectivity in the presentation of the results, an a priori scientific reflection on the naming of the topics therefore seems essential. In addition, transparency regarding the designation of topics and their modification during the process can avoid accusations of civic washing.

TABLE III. EVOLUTION OF THE TOPICS THROUGH EACH SUCCESSIVE PHASE IN LIÈGE.

Phase 1 Ideas	**Phase 2 Votes**	**Phase 3 Results**	**Submitted ideas**	**Selected ideas**
Energy transition			30	11
Social inclusion			47	12
Citizen participation	Participative, collaborative and digital city		154	10
Collaborative practices and creative approaches				
Digital revolution				
	Green spaces, greening, urban agriculture	Greening and urban agriculture	110	14
	Equip, plan and embellish the city	Green, collective and peaceful areas	287	11
	Mobility		180	9
	Art, culture, heritage, toursim		118	10
	Unclassifiable		57	0
		TOTAL	983	77

C. *Analysis of the "likes" and "dislikes"*

The voters had the opportunity to "like" the ideas that they wanted to see implemented, but also to "dislike" some in order to demonstrate their rejection against some proposals. Analyzing the "likes" and "dislikes", a large discrepancy is observed between the two platforms: there are almost 10 times fewer votes in Mons (around 10,000) than in Liège (around 100,000), while it has been possible to vote for 9 months in Mons and only for one month in Liège. In Liège, the voting phase took place distinctively after the submission phase, while these two phases were concomitant in Mons. Thereby, Liège did two distinct communication campaigns (about ideas submission then about votes), while in Mons, communication was all along centered on ideas submission. We suggest the discrepancy is a consequence of the temporal organization of each process, but is also probably linked to the potential number of voters (around 200,000 inhabitants in Liège; less than 100,000 in Mons).

In Mons, out of 910 proposals, only 360 received more than 5 cumulative likes, and only 15 proposals (i.e., 1.6%) got more than 50. The "cumulative likes" here corresponds to the total number of votes, each "dislike" subtracting one point from the total number of "likes", each counting for one point. In Liège, 882/983 proposals received more than 5 cumulative likes, and 514 ideas (i.e., 52%) obtained more than 50. Therefore, the study of "likes" as a legitimization marker of ideas has limited interest for "Demain, Mons" but more meaning for "Réinventons Liège".

To deepen our analysis, we compared the likes to the number of propositions on the same topic. For "Réinventons Liège", as shown in Table 4 below, this radically changes the ranking. In terms of the number of proposals, the category "Green spaces, collective spaces, peaceful spaces" gathers twice as many proposals as other topics. When we look at the cumulative number of likes, yet, the mobility category becomes the priority concern of citizens, with twice as much likes as the second topic. Finally, when we look at the ratio of likes to the number of proposals, it is the "Energy transition" topic that becomes the main concern, with a ratio 40% higher than the second topic.

TABLE IV. COMPARISON OF LIKES AND NUMBER OF IDEAS BY TOPICS FOR "RÉINVENTONS LIÈGE".

Liège/ topics	***Number of ideas***	***Cumulative likes***	***Ratio likes/ideas***
Green, collective and peaceful areas	**287**	12664 (#3)	44 (#7)
Mobility	180	**26446 (#1)**	**136 (#2)**
Participative, collaborative and digital city	154	7760 (#5)	57 (#6)
Art, culture, heritage, tourism	118	10073 (#4)	85 (#5)
Greening and urban agriculture	**110**	**13497 (#2)**	**126 (#3)**
Social inclusion	47	4781 (#7)	106 (#4)
Energy transition	30	6025 (#6)	**194 (#1)**

In that regard, one would wonder which ranking best reflects the citizens' expectations. Our hypothesis is that too many similar proposals lead to the distribution of votes, and as a consequence generate a bias effect in terms of (variety of possible) ranking. To improve the process, it would be interesting for a citizen to be informed of the existence of proposals close to his/her own idea, in order to avoid creating duplicates. Then, before the voting phase, the platform could submit to the citizens an aggregated version of similar ideas, in order to avoid scattering the votes. A smaller number of proposals could also allow each citizen to browse through all the proposals, which was almost impossible to proceed with considering the 1000 proposals of "Demain, Mons" and "Réinventons Liège".

D. *Analysis of the priority actions*

The city of Liège was the only one to go through the whole process and to identify 77 priority actions. Those priority actions have been selected out from every topic, except from the "unclassifiable" one. None of these 57 "out of the box" ideas have indeed been kept as priority actions. Considering the twenty-first ideas submitted by the city, nineteen of them have become priority actions. This pseudo success may reflect two phenomena. On the one hand, the twenty ideas supposed to encourage and inspire participants were projected actions that would probably have been implemented even without the digital platform and the citizen participation. Indeed, those ideas are not necessarily the ones with the highest like-scores: only three of them are in the top 77, but almost all of them will be realized. Furthermore, there is even one proposal that got more "dislikes" than "likes" but still remains a priority action. On the other hand, those twenty ideas impacted the next proposals, which are sometimes similar or even duplicates. Therefore, the number of cumulative "likes" increased and enabled some ideas submitted by the city to rank higher. In addition, even if it was not intended, the first twenty proposals might have put on blinders rather than opened the discussion with the participants, which have certainly been influenced by the twenty-first interpretations of the five imposed topics. This snowball effect testifies either to the importance and the interest related to those ideas apparently reflecting actual citizens' concerns, or to the potential misuse of those digital platforms in a manipulative way.

Moreover, when comes time to determine the priority actions, logic would dictate to select the ideas with the highest number of votes and to transform them into concrete projects. However, considering the dilution effect of the votes between several similar or even identical ideas, this obvious choice would not exactly reflect the citizens' voice. Therefore, in order to rank the submitted ideas (and their associated votes) in a clearer way, we established our own thematic clusters by gathering ideas in subtopics (sometimes associating close, or identical ideas), then organizing them in a tree-like structure and thickening the branches according to the associated cumulative number of likes. At the end of every branch, we also noted the identification code of each related idea in order to ease going back to the full descriptions when needed. Figure 2 is an example of a tree-like structure for the Liège platform, which more precisely structures the ideas generated in regard of the most popular topic, i.e., "Green, collective and peaceful areas". For reasons of scale and readability, we simplify this tree by indicating here the number of ideas for each subtopic rather than the identification codes of all corresponding projects.

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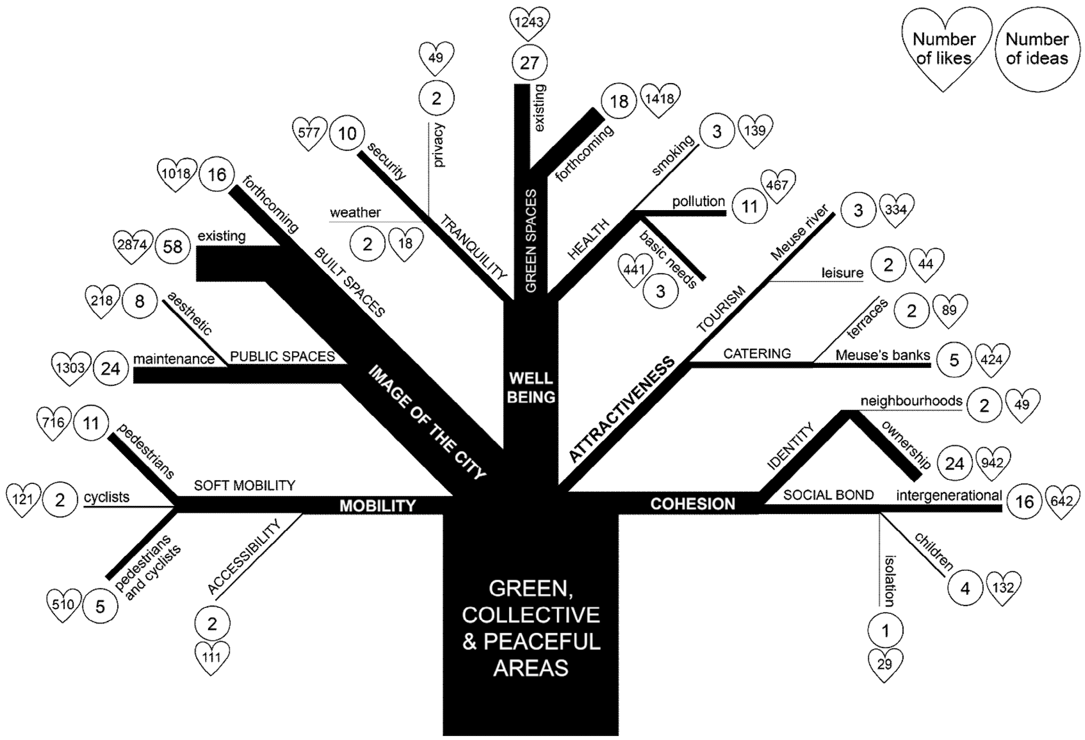

Figure 2. Tree of ideas for the Liège's topic "Green, collective and peaceful areas".

We suggest using the resulting visual map as a decision-support tool, revealing the sub-thematic nodes with the highest citizen interest, i.e., a relative huge number of combined likes and/or proposals that are assimilable and consistent with each other. This could help merging the closest ideas and creating more precise subtopics, which would in turn be useful to navigate on the platform.

V. CONCLUSION

Our analysis of the data generated through two participative platforms, as well as the analysis of the data processing conducted by both cities, highlight several challenges and paths for future improvements. Our analysis of the topics (subsection IV B) underlines the importance of defining clear and distinct topics, as well as transparency regarding their selection and modifications during the process. Our analysis of the likes (subsection IV C) suggests merging and co-managing similar ideas, in order to decrease the risk of scattering the votes and to ease the global visualization of the ongoing process. To achieve that goal, each proposal must contain only one idea, and keywords can be defined by the citizens in order to facilitate the search for similar ideas and allow to summarize and clarify each idea. Another possibility is to limit the number of characters, like on Twitter, which would reduce the risk to receive ideas spanning over multiple topics, but would also considerably impoverish the qualitative understanding of each idea. Concerning the voting phase, our analysis suggests that citizens invest themselves more when this phase takes place after the idea submission phase. Then, our analysis of the priority actions (subsection IV D) shows the necessity of making qualitative content analysis in addition to votes. If an algorithm is used, open source software is a first step towards transparency of the process. Thus, it is essential to think about data processing before creating the platform.

For Mons and Liège, these first attempts of citizen participation platforms served as "digital ideas boxes". In Liège, it seems that the tool has been oriented to legitimize actions previously envisioned by the city. In Mons, it seems it mainly helped to adapt the electoral program for the municipal elections, the decision makers currently trying to transform the consultation into concrete actions. We therefore classify the two platforms as Gov Tech and Citizen consultation tools. According to Arnstein's ladder, consultation is part of symbolic participation because citizens don't get a decision power [6], although one might argue that it depends on how the decision makers eventually use the collected feedback. To achieve this goal in a more participative way, it would be interesting to associate platforms with a participatory budget for instance. The proposals receiving the most votes (considering the previously stated precautionary principles in terms of objectifying the total number of votes) would share the participatory budget and the citizens would realize their idea with the help of city technical services. This would also be a motivation for voting, and more votes would mean more legitimacy for the selected projects.

In the same vein, going one step further, it would be interesting to let citizen co-create the platform. Indeed, our analysis demonstrates the impact of the framework and the process on the results (in terms of topic selection, timing for the voting phase, etc.). Leaving the citizens with the opportunity to co-construct the framework would help to orient the platform towards citizens' concerns rather than reflect political projects. Hackathons or Living Labs would be appropriate ecosystems to conduct such co-creation. Hackathons, as well as participatory budgets are classified by Douay (see Table 1) as co-design tools and constitute forms of "contribution" in regard of the ladder of citizen participation. Involving citizens in every step would promote empowerment and civic engagement, which would make digital platforms a Civic Tech tool. Thus, digital platforms for citizens participation could serve different levels in the ladder of participation, depending on their framework, their underlying process and the goal pursued by the project managers.

Side-by-side with such digital platforms, we suggest that face-to-face exchanges would foster additional debates and offer complementary richness through dialogue. Given the complexity of smart urban challenges, participants indeed often need some support in order to extract and produce concrete ideas from their citizen expertise, based on their past experiences, actual needs and perceptions. We therefore suggest that more "traditional" participatory modes, especially co-design workshops with lay people and professional experts, offers additional added values in regard of digital platforms and enable participants to move from concerns to projects. Moreover, in-person participation gives depth to an idea, does not limit to a one-shot online submission and this way can be enhanced and justified through the workshop

Eventually, we emphasize here that it is normal to encounter difficulties when setting up a new tool, and that our neutral, remote assessment should nurture a process of continuous improvement. In that regard, we particularly insist on the fact that technical and administrative support is essential to ensure that the citizens understand the feasibility criteria before making suggestions that would anyway be automatically rejected by the city officials during the analysis phase. Such technical and administrative support could be administered through the various meetings, info sessions and conferences organized prior and during the whole idea generation process. Additionally, communicating the results of this evaluation to the citizens would be a recognition of their commitment and an encouragement to pursue participation in the future.

In terms of future work, analysis should be conducted about the participants (their age, gender, profession, socio-economic profile, etc.) in order to reach a better understanding of the citizens' representativity, and possible digital divide, and thus analyze the impact such digital participation platforms might have on the representativity issues.

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WiFi and LoRa Energy Consumption Comparison in IoT ESP 32/ SX1278 Devices

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Abstract—**The use of Internet of Things (IoT) devices has spread through many different fields. Transport, health, and energy management of farming are some of the areas where IoT systems are being utilized. The selection of the wireless communication technology for the IoT system is paramount for its optimal performance. However, factors such as desired coverage or energy consumption must be considered for this selection. In this paper, several tests to determine the battery life that can be obtained after performing WiFi and LoRa Low Power Wide Area Networks (LPWAN) transmissions with a low-cost IoT device has been performed. With a 5 second transmission interval and default settings, similar results were obtained for both WiFi and LoRa. Furthermore, WiFi outperformed LoRa with the default settings and a 30 second transmission interval. Lastly, LoRa did outperform WiFi when the settings where changed so as the transmission power of LoRa was that of 10 dBm.**

Keywords-Energy consumption; battery life; WiFi; LoRa; transmission power.

I. INTRODUCTION

Currently, IoT devices are used in a wide variety of areas. According to IoT Analytics [1] the areas where IoT was most used in 2018 are Smart homes, Wearables, Smart Cities, Smart grids, Industrial internet, Connected cars, Connected Health (Digital health / Telehealth / Telemedicine), Smart retail, Smart Supply chain and Smart farming. In order to improve the performance of the implanted systems, it is necessary for the results observed by the sensors to be sent to other systems. The processing and storage capacities of IoT devices are generally very limited. Usually, in the case of wanting to correct an error or wanting to optimize the performance of the observed elements or environments, after processing the data, the appropriate corrective measures are taken to optimize the observed functions. To transmit the information, which is captured by the sensors connected to the nodes, both wired and wireless technology are used depending on the ease of installation of the physical infrastructure in the observed areas.

In a large number of cases, the sensors used to monitor the IoT devices need to establish a wireless communication to transmit the observed data. Garcia et al. [2] presented a review of wireless technologies that were employed in Smart cities, their comparison and the problems that make their coexistence difficult.

One of the areas in which the use of wireless technology becomes more evident is in Smart farming. Currently, it is very difficult to connect IoT devices that are located in large tracts of land through a wired network. In addition, when using agricultural machinery, which is often heavy vehicles, it is very difficult not to deteriorate or break the copper or fiber optic wires deployed in the fields. It is very easy for situations to appear where the tools attached to the vehicles can drag the cables. For this reason, Smart farming is one of the ideal areas where wireless technology should be used. Aspects such as foliage density, which can change according to the seasons or depending on the growth state of the plant, should be considered as they can affect the wireless transmission. These types of smart systems for agriculture monitor parameters such as irrigation, the humidity and temperature of the soil or the environmental conditions.

There is a wide range of wireless technologies, among which we can highlight those that comply with the IEEE wireless standards such as IEEE 802.11 [3], IEEE 802.15 [4], and IEEE 802.16 [5]; we also find mobile technologies such as 3G [6], 4G, 5G. In addition, we can find other proprietary technologies such as LoRa [8], NB-IoT [9], and Sigfox [10].

In some situations, it is necessary to use a large number of sensor nodes. Obviously, the cost of the nodes, if they are used in large numbers, can be prohibitive. In addition, if mobile technologies are used to establish transmissions, such as 4G or any other, the cost of the node is significantly increased, and maintenance is also expensive. Furthermore, it would be necessary to hire the services of a mobile operator that has coverage in the space that will be monitored.

We have observed that inexpensive nodes that include wireless technologies are available on the market. Among the most currently employed we can find nodes that include IEEE 802.11n interfaces, Bluetooth Low Energy (BLE) and LoRaWan.

One of the main problems that we found when implementing a solution is the energy consumption of the nodes. If the nodes remain active in real time, to know at any moment the parameters that are considered necessary, they will consume a large amount of energy. Assuming that the nodes are distributed in dispersed locations, where it is not

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possible to bring the energy at reasonable costs, the supply of electrical power can become a big problem. Depending on the needs of different crops, the observation time may vary, but if the difference in energy consumption of the nodes is based fundamentally on the employed wireless technology, our interest is focused on selecting the most appropriate technology, so that energy consumption is minimal.

For all the reasons described previously, we have carried out some tests to identify which of the two wireless technologies considered in this paper can be used in such a way that it extends the transmission capacity as much as possible, provided that the transmitted data are identical. In our work we have studied WiFi and LoRaWan technologies, which are supported by our sensor nodes.

The rest of the paper is organized as follows. Section 2 presents the related work. A background in WiFi and LoRa technologies is presented in Section 3. The testbed is explained in Section 4. Section 5 depicts the obtained results. Lastly, the conclusion and future work are presented in Section 6.

II. RELATED WORK

In this section, the related work on energy consumption studies for WiFi and LoRa is going to be presented.

When selecting the communication technology for an IoT deployment, the energy consumption is one of the most considered factors. Several papers focus on determining the energy consumption of LoRa and WiFi.

Ayele et al. [11] performed a simulated comparison of the energy consumption of BLE and LoRa in a Wildlife Monitoring System. The authors proposed a dual radio network model. The nodes were deployed on the collars of the animals. The communication between the nodes was performed over BLE until it reached a cluster head. Then, the cluster head communicated through LoRa to a Lora gateway. The energy consumed by the LoRa star topology increased as the nodes increased, due to the overhead. However, the proposed solution eliminated the energy consumption caused by the overhead. The results showed a reduction of energy consumption of 97% compared to LoRaWAN. Bor et al. [12] presented an analysis of the parameters of LoRa transmissions. The authors focused on the effects of parameter selection in energy consumption and communication performance. The authors stated that an Spreading Factor (SF) of 8, a bandwidth of 500 MHz, 4/5 coding rate and 8dBm of transmission power (tx power) consumed 2.31 mJ and the optimal settings were a SF of 7, a bandwidth of 500 MHz, a coding rate of 4/5 and a tx power of 11 dBm which had an energy consumption of 1.60 mJ. Furthermore, the authors proposed an algorithm that was able to probe different settings and selected the best option in order to balance the energy consumption. Several experiments on the Carrier Sense Multiple Access (CSMA) channel access mechanisms of LoRa were performed by Phan [13]. The author presented an adaptation of the 802.11 CSMA protocol for LoRa and a new CSMA protocol. The energy consumption of the adaptation and the new proposal with different settings was compared as well. The results showed the new proposal had a lower energy consumption for all settings compared to the adaptation from 802.11. Moreover, Pötsch et al. [14] discussed the limitations of LoRa gateway deployment. The overhead caused by the LoRa gateways is analyzed as well. The energy consumption was compared for different spreading factors and bandwidths of 125MHz, 250 MHz and 500 MHz. The results showed less energy consumption as the spreading factor decreased and the bandwidth increased. Furthermore, the energy consumption increased as the tx power increased, being 50 mA approximately for a tx power of 5 dBm and slightly above 120 dBm for a tx power of 19 dBm.

The energy consumption of WiFi nodes has been studied as well. Mesquita et al. [15] performed a study on the performance of ESP8266 WiFi modules which are branded as ultra-low power. The authors performed several experiments to measure the energy consumption with sleep modes and different transmission configurations. The authors stated that the usual configuration of a Delivery Traffic Indication Message (DTIM) period of 3 and a 100 ms beacon interval had the lowest average current consumption, namely 14.71 mA. They also stated that ESP8266 modules were able to operate for 2 to 4 days with a small battery of 1000mAh of capacity. Montori et al. [16] presented a performance study on WiFi for IoT systems. The authors utilized ESP-12 SoC modules to study their energy consumption under variations of the connectivity settings. Tests were performed with Lo-Po, alkaline and NiMH batteries. The results showed similar performances for all batteries with the same configurations. Furthermore, the difference in energy consumption between awake and sleep mode was less than that stated on datasheets. Lastly, Putra et al. [17] performed an energy consumption comparison between BLE and WiFi with different settings for the beacons. Tests were performed for an iPhone device. The results showed BLE had a 30% more energy efficiency than WiFi. Furthermore, the battery life of the smartphone was of 14 hours and 46 minutes for WiFi and 16 hours and 38 minutes for BLE.

To the best of our knowledge, no comparison between the energy consumption of WiFi and LoRa in IoT devices has been performed before. Therefore, in this paper, we compare the effects of WiFi and LoRa transmissions on battery life.

III. WIFI AND LORA TECHNOLOGIES

The two wireless technologies on which we have done our work are IEEE 802.11 (also known as WiFi) and LoRa. Next, we will describe the main characteristics of both technologies.

A. IEEE 802.11 technology

In this subsection, a background on the IEEE 802.11 standards is going to be provided.

The 802.11 standards use the 2.4 GHz and 5 GHz bands. These bands are known as Industrial, Scientific and Medical (ISM) radio bands. They are defined in Article 5 of the Radio Regulations of the International Telecommunication Union (ITU) [18]. These bands do not need a license for their operation, but they differ according to the regulations of each country. The problem that can arise when using them is that

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other devices can create interference if they work in the same bands.

The modulation techniques most used by the standard are: Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (QAM), Direct Sequence Spread Spectrum (DSSS), Complementary code keying (CKK) and Orthogonal Frequency Division Multiplexing (OFDM).

There are three types of frames that are used by the standard: data frames, control frames and management frames.

Data frames transport data between connected stations. The control frames next to the data frames are used to carry out area cleaning operations, channel acquisition and maintenance functions associated with the carrier and acknowledgments (ACK). The management frames are used to join or leave the wireless network and move associations of access points. All data frames that are transmitted must have an Acknowledgment of Receipt (ACK), otherwise the transmission will be considered failed.

Figure 1 shows a generic 802.11 data frame. An important difference that can be appreciated, if we compare it with an Ethernet frame, is the larger size of the data field. While a standard Ethernet II frame has a size of 1500 bytes, the data field of an 802.11 frame reaches up to 2312 bytes.

Frame Control	Duration ID	Add 1 receiver	Add 2 sender	Add 3 filtering	Seq-ctl	Add 3 optional	Frame Body	FCS
2 Bytes	2 Bytes	6 Bytes	6 Bytes	6 Bytes	2 Bytes	6 Bytes	0 – 2312 Bytes	4 Bytes

Figure 1. 802.11 generic data frame

The ACK frames have a much shorter length, only 14 bytes. Other frames that should be highlighted in the standard are the Request to Send (RTS) and Clear to Send (CTS) frames. RTS and CTS frames are used to avoid collisions. The size of the CTS frame is 14 bytes while the RTS frame has a length of 20 bytes.

Within the IEEE 802.11 standard, our nodes have implemented the IEEE 802.11n, but working in the 2.4 GHz band. As defined in the standard, if 20 MHz channels are used, the theoretical maximum data transmission speed is of 72.2 Mbps, and if 40 MHz channels are used, the maximum theoretical data transmission speed is of 150 Mbps, when a single stream of spatial data is transmitted.

With regard to power management, the 802.11 standard has a defined system. It is a mechanism that allows energy savings and is called Power Saving. The stations that work in that mode are known as PS-STAs (Power Save Stations). In order for them to work properly, their control must be carried out by an Access Point (AP). The AP must have all the PS-STAs registered. If a station is not active, the AP will store the packets that are directed to the station until it requires them. Periodically, the stations must be activated in order to listen if the AP has data for them.

B. *LoRa technology*

In this subsection, a background on LoRa and the structure of LoRa packets is going to be provided.

LoRa stands for Long Range and is a patented spread spectrum technology developed by Semtech Corporation. LoRa operates in the lower ISM bands (EU: 868MHz and 433 MHz, USA: 915MHz and 433 MHz). The transmission data rate can be from 0.3 kbps to 27 Kbps with a bandwidth of 125 KHz. It is widely used for Machine To Machine (M2M) applications from IoT.

LoRa uses a modulation technique derived from Chirp Spread Spectrum (CSS). It applies an adaptive modulation technique with a multichannel multimode transceiver in the base station to receive a multiple number of messages from the channels. The relationship between the required data bit rate with the chirp rate and the symbol rate in the LoRa modulation technique [19] is defined as follows:

$$R_b = SF \cdot 1 / (2^{SF}/BW) \ \ bits/s \qquad (1)$$

where Rb is the modulation bit rate for LoRa, SF is the scattering factor and BW is the modulation bandwidth in Hz. As seen in (1), the data rate Rb is directly proportional to the scattering factor SF.

Figure 2 shows the structure of a LoRa packet.

Preamble	Header	CRC	Payload	Payload CRC
Min. 4.25 symbols	4 Bytes		Max. 255 Bytes	2 Bytes

Figure 2. Structure of a LoRa packet.

SF is the ratio between the symbol rate and chip rate. The higher the dispersion factor, the higher the Signal to Noise Ratio (SNR). The number of chips per symbol is calculated as 2^{SF}. For example, if the scattering factor SF is 12, 4096 chips / symbol are used. Each time SF is increased, the transmission speed is halved. This causes the duration of the transmission to be doubled, which leads to an increase in energy consumption.

The nodes are transmitted directly to a gateway that connects to the backbone network. Gateways are capable of receiving and decoding multiple simultaneous transmissions (up to 50).

Three node classes [20] have been defined:

1) *Class A devices:*

The node transmits to the gateway when necessary. After transmission, the node opens a reception window to obtain messages from the gateway.

2) *Class B final devices with programmed reception spaces:*

The node behaves like a Class A node but opens additional reception windows at scheduled times. Beacons from the gateway are used for the timing of the end devices.

3) *Class C terminal devices with maximum reception spaces:*

These nodes are continuous listening, which makes them unsuitable for battery operations.

To configure a LoRa interface, we must take into account the following four parameters: carrier frequency, spreading factor, bandwidth and coding rate. Depending on the parameters that are selected, the energy consumption, transmission range and resilience to noise will be determined.

IV. TESTBED

In this section, the node and the explanation of the test are going to be presented.

In order to perform the tests on energy consumption, we utilized the Heltec WiFi LoRa 32 node which is presented in Figure 3. It is able to transmit with both WiFi and LoRa. This node has an ESP32 microprocessor and a LoRa SX1278 node chip. It has an SH1.25-2 battery interface onboard as well and an integrated management system for lithium batteries so as to manage charge and discharge, switch automatically between USB and battery power, protect against overcharge and detect battery power. It also has an integrated OLED (Organic Light-Emitting Diode) display, a CP2102 USB to serial port chip and supports the Arduino IDE (Integrated Development Environment). It is comprised of 29 general GPIO (General Purpose Input7Output) ports. It has 3 UART (Universal Asynchronous Receiver-Transmitter) ports, 2, SPI (Serial Peripheral Interface) ports, 2 I2C (Inter-Integrated Circuit) ports and one I2S (Inter-IC Sound) port. It also has a 4 MB flash memory. Table 1 shows the energy consumption provided by the manufacturer [21].

In order to perform the tests, the Heltec WiFi LoRa 32 v2 was programmed using the Arduino IDE. The WiFi.h and LoRa.h libraries were utilized to establish the connection between the two Heltec WiFi LoRa 32 v2 nodes. The default settings were utilized for both WiFi and LoRa. Table 1 shows the default settings for LoRa. The forwarded data was the same for both WiFi and LoRa transmissions and it had a length of 80 bytes.

Tests were performed forwarding a packet with a 5 second interval and a 30 second interval. The utilized battery was a 4955 power bank with a capacity of 2000 mAh and an output of 5V DC and 1000 mAh.

V. RESULTS

In this section, the obtained results are going to be presented.

The tests on the energy consumption of WiFi were performed for the two selected transmission time intervals. Figure 4 shows the average battery life for each transmission interval. As it can be seen, a difference of 1 hour was obtained between transmitting with each time interval. For the time interval of 5 seconds, the obtained battery life was 10 hours and 10 minutes whereas 11 hours and 14 minutes of battery life was obtained for the 30 seconds time interval. Therefore, the transmission interval can severely affect the energy consumption of the devices that utilize WiFi for their communication.

The tests performed with LoRa considered 5 seconds and 30 seconds time intervals as well. However, no significant differences were obtained between both transmission intervals. In fact, the average battery life for the 30 seconds transmission interval was 26 minutes less than that of the 5 seconds transmission interval. As it can be seen in Figure 5, the lifetime of the battery was approximately 10 hours.

As the manufacturer stated, the power consumption for both WiFi and LoRa transmissions is practically the same with transmission powers of 17 dBm or 18 dBm. It is surprising as LoRa is branded as a low-power consumption communication protocol. Therefore, the transmission power of LoRa has to be decreased so as to improve its battery consumption, which leads to less coverage.

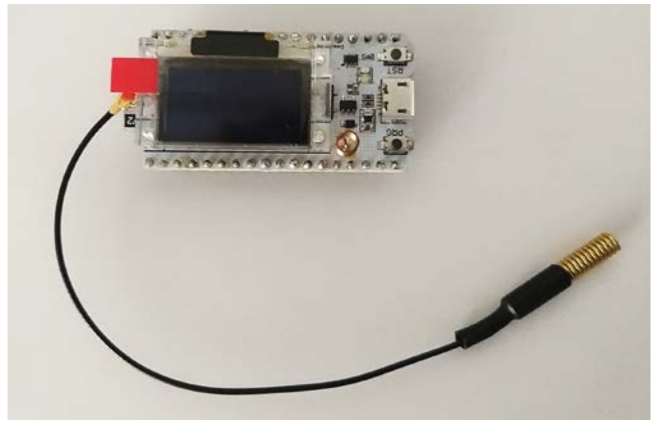

Figure 3. Utilized Heltec WiFi LoRa 32 node

TABLE I. ENERGY CONSUMPTION OF THE NODE

Mode	Energy consumption
LoRa 10 dB tx power	50 mA
LoRa 12 dB tx power	60 mA
LoRa 15 dB tx power	110 mA
LoRa 20 dB tx power	130 mA
WiFi AP mode	135 mA
WiFi scan mode	115 mA

TABLE II. ENERGY CONSUMPTION OF THE NODE

Tx Power	17 dB
Frequency	433 MHz
SF	7
Signal Bandwidth	125 KHz
Coding rate	4/5
Preamble length	8 Symbols

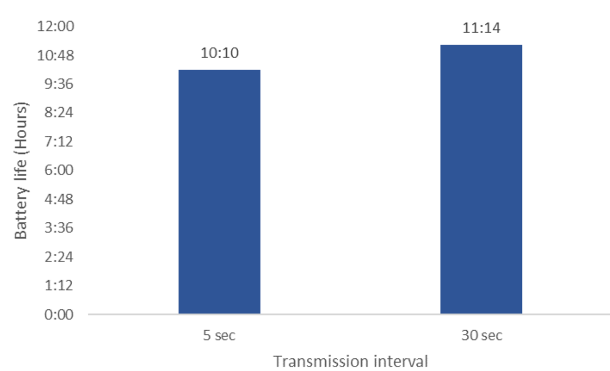

Figure 4. Battery life with WiFi communication

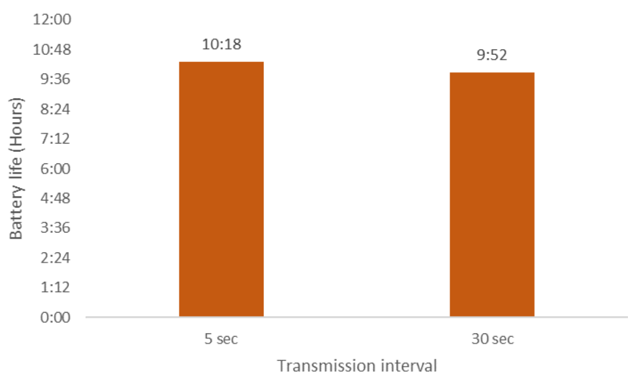

Figure 5. Battery life with LoRa communication

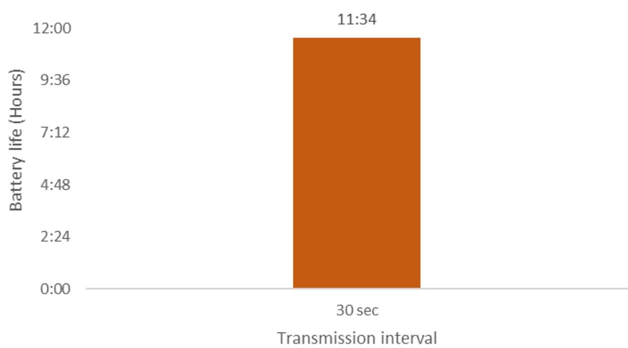

Figure 6. Battery life with LoRa communication and 10 dBm of tx power

To assess if the battery life was increased when transmitting with less transmission power, another test was performed changing the tx power of the LoRa transmissions to 10 dBm. The time interval for this test was 30 seconds. The average battery life for this case is presented in Figure 6. As it can be seen, the battery life improved compared to that with a transmission power of 17 dB, obtaining more than one hour more of battery life. Furthermore, the battery life surpassed that of WiFi with a transmission interval of 30 seconds in 20 minutes. The difference would be then more noticeable when utilizing batteries with more capacity. However, the overall difference between the power consumed by both technologies is not that great. Therefore, other factors, such as the range that can be reached with each technology or the data rate may be the factors to be considered when selecting the wireless technology to be utilized in an IoT system.

VI. Conclusion and Future Work

When designing an IoT system, the selection of the communication technology is of great importance. LoRa is supposed to have less power consumption than WiFi but the difference is not that evident and LoRa settings have to be changed to lower transmission power values, lower SF and increase bandwidth for it to consume less power. In the case of the Heltec WiFi LoRa 32 device, similar results have been obtained for both LoRa and WiFi with the default settings and 5 seconds of transmission interval. However, WiFi outperformed LoRa with a 30 second transmission interval. A similar battery life was obtained when lowering LoRa transmission power to 10 dBm.

As future work, we will implement WiFi and LoRa in an agriculture and irrigation monitoring system selecting the technology depending on the range that needs to be reached.

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Predicting Incidents of Crime through LSTM Neural Networks in Smart City Domain

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***Abstract*—Crimes are common social problems that affect the quality of life, economic growth and reputation of a country. In smart cities, the aim is to reduce crime rates using Information and Communication Technologies (ICT), specifically with the use of Internet of Things (IoT) technology in combination with legacy information systems, in order to obtain data automatically. In this paper, we propose an approach based on deep learning for the classification of incidents of a crime of public safety through predictive analysis. The predictive model is based on a neural network Long Short-Term Memory (LSTM), trained with a small group of attributes, enabling the prediction of the class label in the validation stage, with a high percentage of prediction accuracy. The proposed approach is evaluated through a big data set (real data) of type open data, which contains historical information about the crimes of a smart city.**

Keywords-LSTM; Prediction; Neural Network; Data Classification; Smart City.

I. Introduction

Nowadays, smart city approaches are developed in order to improve the economy, mobility, environment, people life, living standards, and governance of cities [1], supported by the design, implementation, management, and monitoring of projects based on Information and Communication Technologies (ICT). The main smart city characteristics include sustainability, resilience, governance, enhanced quality of life and intelligent management of natural resources and city facilities [2]. In this way, for the development of the services deployed in the complex systems of intelligent cities, the Internet of Things (IoT) technologies have emerged as a new computational paradigm.

The IoT consists of a large number of objects (physical and virtual things) with pervasive sensing, detection, actuation, and computational capabilities, allowing these devices to generate, exchange, and consume data with minimal human intervention [3]. Contributions from the implementation of IoT technologies can be found in smart cities, smart homes, e-health, smart grids, intelligent transportation systems, crime prevention systems, and intelligent use of water, among others. The extensive use of information systems (smart type) in various domains of the city, as well as the use of smart devices in people's daily life, have as a consequence the production of massive volumes of data [4], known as big data. These data are generated by human-to-human, human-to-machine, and machine-to-machine interactions. The big data volumes consist of a mixture of complex data characterized by large and fast-growing data sets [2], which exceed the analysis capabilities of the current data management systems. Therefore, there are requirements related to the acquisition and storage of data, the processing of information, and the development of algorithms for intelligent decision support systems. In addition, the monitoring, understanding, and analysis of the data generated by the information systems using algorithms based on data mining and machine learning, can be used to advance their contribution to the goals of sustainable development in a smart city [5]. The public safety data set of smart cities holds a large amount of crime data that could be exploited to discover patterns and predict future crime trends [6]. The predictive analysis aims to optimize the exploitation of these data in order to use knowledge discovery to anticipate criminal events [6] [7].

Deep learning techniques have demonstrated their capability of the discriminative power compared with other machine learning methods. Recurrent Neural Network (RNN) architecture has become a model of the deep learning techniques most successfully implemented in different domains, due to its natural ability to process sequential entries and to know their long-term dependencies [8]. That is, RNN is designed to utilize sequential information of input data with cyclic connections among building blocks. In the RNN, neurons are connected to each other in the same hidden layer and a training function is applied to the hidden states repeatedly [8]. The Long Short-Term Memory (LSTM) neural network is an extension of the RNN, which has achieved excellent performance in various tasks, especially for sequential problems [9]-[11]. The implementation of LSTM neural networks for the prediction of the class label (classification) from a set of instances through predictive analysis can be considered an important strategy as a technique in the context of supervised machine learning and data mining.

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In this paper, we propose a deep learning-based predictive analysis approach for the classification of crime incidents. The predictive model is based on an LSTM neural network that is trained with a small number of attributes of the big data set, enabling the prediction of the class label in the validation phase. In order to validate the approach and show the applicability to the public safety domain, we present preliminary results using a data set with 6.9 million registers. The test carried out on the trained LSTM network shows that it has the capacity to predict the class label of a new instance. For the evaluation of the system model, we present a case study with data collected by a real smart city system in Chicago, USA. This system combines IoT devices and legacy system in smart city domain. Our case study addresses the challenges of data analytics of smart city public safety. In addition, a methodology is proposed to guide the preprocessing and categorization of the input data to the neural network, as well as the design and training of the network.

The rest of the paper is structured as follows. Section II presents a background review on LSTM neural network. Section III presents a methodology proposed to construct the predictive model. Section IV discusses the findings, while Section V we discusses the related work. Section VI provides the conclusions and plans for future work.

II. RESEARCH PROPOSAL

An LSTM neural network is considered a network with a special structure consisting of memory blocks and memory cells, together with the gate units (input, forget, and output) that contain them [12]. This structure allows the LSTM network to select which information is forgotten or remembered (see Figure 1). The multiplicative input gate units are used to avoid the negative effects that unrelated inputs can create.

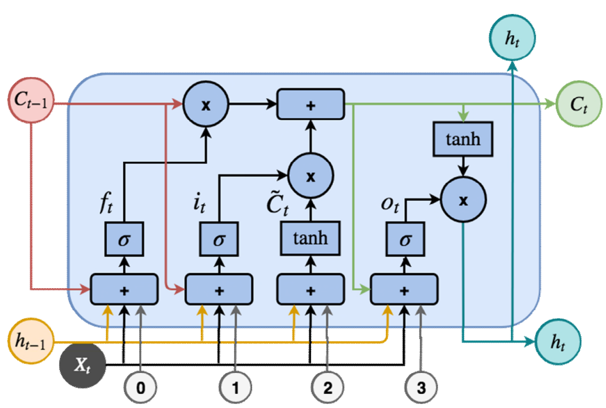

Figure 1. Structure of an LSTM cell.

In our proposed approach, the following is considered for the definition of the neural network model: 1) the *input gate* controls the input flow to the memory cell, 2) the *output gate* controls the output sequence of the memory cell to other LSTM blocks, and 3) the *forget gate* in the structure of the memory block is controlled by a single-layer of the neural network, as shown in Figure 1.

The operation of the LSTM network is based on equations (1), (2), (3), (4), and (5) [10][13]. Then, the components of the LSTM units, at a time t are updated by (1), where x_t is the input sequence, h_{t-1} is the previous block output, C_{t-1} is the previous LSTM block memory, and b_f is the polarization vector; W represents separate weight vectors for each input, and σ is the logistic sigmoid function.

$$f_t = \sigma(W_f \times [x_t, h_{t-1}, C_{t-1}] + b_f) \quad (1)$$

$$i_t = \sigma(W_i \times [x_t, h_{t-1}, C_{t-1}] + b_i) \quad (2)$$

$$C_t = f_t \times C_{t-1} + i_t \times tanh\,(W_C \times [x_t, h_{t-1}, C_{t-1}] + b_C) \quad (3)$$

$$o_t = \sigma(W_o \times [x_t, h_{t-1}, C_t] + b_o) \quad (4)$$

$$h_t = o_t \times tanh(C_t) \quad (5)$$

On the other hand, the input gate is divided into two networks and its function is to generate the new memory, as shown in Figure 1. First, a single-layer neural network takes the same inputs as the previous gate, which has a sigmoid activation function. In this part of the network, it is decided what percentage of the new memory will be influenced by the memory of the previous block. Second, a single-layer neural network, with an activation function *tanh*, generates a new memory from the input vectors (x_t) and the output from the previous block (h_{t-1}). Finally, a multiplication of vectors is performed with the outputs of the two simple neural networks, and the result is added to the output of the forgetting gate. This process is performed by equations 2 and 3. Finally, the output gate is calculated by means of equations 4 and 5, generating the probability value of the current LSTM block. In summary, the input to the cells is multiplied by the activation of the input gate, the output to the network is multiplied by that of the output gate, and the previous cell values are multiplied by the forget gate.

III. METHODOLOGY

The prediction of the class label is done by implementing a set of stages, which can be grouped into pre-processing, categorization of the data, and predictive model, as shown in Figure 2. The proposed methodology consists of three phases: data pre-processing, categorization, and construction of the predictive model. These phases allow the prediction of the label of a class based on a model of an LSTM neural network

A. Phase 1: Data Pre-processing

The data pre-processing phase consists of the following stages:

1) Data Extraction: In the data extraction stage, several activities are carried out sequentially. First, a set of attributes are extracted from the original data set. This is performed through the execution of a feature selection algorithm proposed in "in press" [14], generating a new data

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group that will be used for the training of the neural network. Then, in the training data set, a normalization task is performed on the attribute that represents the class. Subsequently, a cleaning process is executed to detect and remove the corrupt or inaccurate instances in the database. Moreover, the attributes that contain values of a numeric type are updated, adding the first character of the name of the attribute to the value of the variable.

2) Segmentation: The segmentation task is applied to the data set generated in the previous stage. This task consists of creating a list of all the features of an instance and implementing a criterion of separation between features. Each feature is represented as a unique integer, converting the instances into a sequence of integers, thereby generating two lists of the sequence of integers. The former consists of input features (X), and the later of the output feature (Y), i.e., the class. Then, the input feature (X) is transformed into a two-dimensional matrix (the number of sequences and the maximum length of sequences).

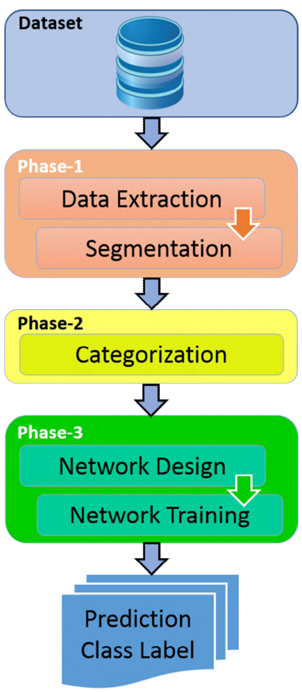

Figure 2. Methodology implemented for class prediction.

B. Phase 2: Categorization

The intermediate categorization phase consists of a process to categorize the sequence of integers corresponding to the output activities (Y), in a one-hot encoding representation type, specifying that the number of classes will be equal to the size of the vocabulary.

C. Phase 3: Prediction Model

The prediction model phase based on LSTM network is composed of the following stages:

1) Network Design: In our approach, the design of the neural network consists of generating a set of three layers. The input layer is created based on a word embedding method. The hidden layer contains the memory cells, where each cell is an LSTM unit. This layer contains a set of LSTM cells that are composed of the input, output and forget gates, which allow their interconnection. In the output layer, only one neuron will be available since there is a unique output value corresponding to the prediction. This is shown in Figure 1, where x_t is the input vector and h_t is the output result to the memory cell at time *t*. Furthermore, h_t is the value of the memory cell. At time *t*, it, ft and ot are values of the input gate, the forget gate and the output gate, respectively. Finally, C_t are values of the candidate state of the memory cell at time *t*.

2) Network Training: The training of the LSTM network is performed using as training data, the integer sequence list represented by the features contained in the two-dimensional matrix (X) and the vector that contain the class (Y) through of a representation one-hot encoding. We use the configuration parameters presented in Table I.

D. Prediction Class Label

The prediction is the output generated by the LSTM neural network, which, through a training phase, allows predicting the class label for a new instance, from a set of input features of an instance, which is explained in the following section.

TABLE I. CONFIGURATION PARAMETERS OF THE LSTM NETWORK.

Parameter	***Value***
epochs	500
batch size	32
optimizer	Adam
loss	categorical_crossentropy
LSTM	units 50

IV. EXPERIMENTAL RESULTS

Crimes are common social problems that affect the quality of life, economic growth and reputation of a country [15]. In smart cities, the aim is to reduce crime rates using ICT. Through different information systems, data is collected automatically, with the intention of generating knowledge that allows decisions to be made to reduce the criminal index. In this sense, our proposal aims to predict the value of a class, from a set of attributes. The class prediction represents the probability that an individual will be arrested after committing a crime.

The data set used is of type open data and contains historical information about the crimes to evaluate the performance of the proposed LSTM model. This data set of the reported incidents of crime that occurred in the City of Chicago from 2001 to 2018. The data set is composed of 22 attributes and 6.9 million records or instances. The complete data set can be found in [16]. Some of these attributes were

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generated automatically by IoT devices, such as x-coordinate, y-coordinate, latitude, longitude, location. The attributes can be of data type: string, numeric, date, location or Boolean. The data is extracted from the Chicago Police Department's CLEAR (Citizen Law Enforcement Analysis and Reporting) system. The data set contains data from arrests, including data on Illinois Uniform Crime Reporting (IUCR), location description, domestic, date, ward, Federal Bureau of Investigation (FBI) code and more data fields. An extract from the data set is shown in Table II.

TABLE II. EXCERPT OF THE INCIDENTS OF CRIME DATA.

ID	*UICR*	*District*	*Ward*	*Com. Area*	*FBI Code*
50	479	001d	4w	32c	04B
51	820	019d	44w	6c	6
52	820	008d	18w	70c	6
53	326	006d	6w	69c	3
54	031A	025d	31w	19c	3
55	041A	007d	20w	68c	04B
56	1752	010d	12w	30c	17
57	1750	003d	5w	43c	08B
58	630	019d	2w	7c	5
59	553	022d	19w	74c	04A
60	650	010d	24w	29c	5
61	1320	009d	15w	61c	14
62	550	004d	7w	43c	04A
63	1562	006d	21w	71c	17
64	041A	017d	35w	14c	04B
65	1130	018d	42w	8c	11
66	5001	022d	19w	72c	26
67	1195	025d	29w	25c	11
68	1154	008d	13w	62c	11
69	1153	018d	43w	7c	11
70	620	018d	42w	8c	5

The feature selected to predict the label class are: UICR (Illinois Uniform Crime Reporting), District, Ward, Com. Area, and FBI Code. Table III shows a complete description of the attributes and the number of cases that were identified within the data set. The class to predict is a Boolean type, that is, *arrest = false* or *arrest = true*.

TABLE III. DESCRIPTION OF THE FEATURES SELECTED OF THE DATA SET.

Feature	*Description*	*# cases*
UICR	Illinois Uniform Crime Reporting (IUCR) codes are four-digit codes that law enforcement agencies use to classify criminal incidents.	350
District	Indicates the police district where the incident occurred.	25
Ward	The ward (City Council district) where the incident occurred.	50
Com. Area	Indicates the community area where the incident occurred.	77
FBI Code	Indicates the crime classification as outlined in the FBI's National Incident-Based Reporting System (NIBRS).	26
Arrest	Binary variable that indicates whether a criminal was arrested.	2

In our experiment, training data sets with 80% of the observations of the original data set are used to train our model. Instances of the training data set were selected by a random method, automatically. The remaining 20% of the instances are used to test our model prediction accuracy.

Table IV presents an extract of the results obtained in the prediction of the LSTM network using the crime data set presented before. In the column "Input Features", it is mentioned the group of the features used as a new input in the LSTM network for the prediction stage. The values of the "Input Features" column are formed by the IUCR code, district and ward id's, as well as the identifier of the community area and the FBI code. The "Target Class" is the expected label for the corresponding input instance, that is, the class label with the highest probability of prediction by the neural network, based on the weights of each class label. Each row in the table shows a case of prediction of the class from the input one. The "Output Class" column presents the label or value that the LSTM neural network predicted from the input instance for the "arrest" class.

In the column "% of prediction" (see Table IV), the probability of prediction for each instance is shown. It can be observed that, in some cases, the neural network fails to predict the class (for example 3, 7, and 18). However, in most cases, the neural network has a correct prediction of the value of the expected class. The global percentage of the prediction accuracy of the LSTM network for the complete data set is 0.87.

TABLE IV. AN EXTRACT OF THE PREDICTION FROM THE LSTM.

#	*Input Features*	*Target Class*	*Output Class*	*% of prediction*
1	0265, 011d, 28w, 29c, 02	false	false	0.82
2	0620, 025d, 31w, 22c, 05	false	false	0.97
3	0560, 005d, 34w, 53c, 08A	true	false	0.77
4	0430, 018d, 2w, 8c, 04B	false	false	0.90
5	0312, 010d, 28w, 31c, 03	false	false	0.99
6	1754, 008d, 18w, 66c, 02	true	true	0.50
7	0860, 018d, 27w, 8c, 06	true	false	0.53
8	0281, 018d, 2w, 8c, 02	false	false	0.99
9	1130, 012d, 11w, 28c, 11	false	false	0.99
10	2825, 006d, 8w, 44c, 26	false	false	0.99
11	0890, 001d, 3w, 35c, 06	false	false	0.99
12	1153, 006d, 21w, 71c, 11	false	false	0.99
13	0910, 011d, 28w, 27c, 07	false	false	0.91
14	1150, 008d, 23w, 56c, 11	false	false	0.99
15	1120, 001d, 42w, 32c, 10	false	false	0.99
16	0890, 018d, 2w, 8c, 06	false	false	0.99
17	1150, 001d, 4w, 32c, 11	false	false	0.97
18	1330, 005d, 9w, 53c, 26	false	true	0.79
19	0281, 003d, 20w, 69c, 02	false	false	0.99
20	1153, 025d, 37w, 23c, 11	false	false	0.99
21	0560, 010d, 24w, 29c, 08A	false	false	0.84
22	0820, 024d, 49w, 1c, 06	false	false	0.95
23	0110, 015d, 28w, 25c, 01A	false	false	0.88
24	1150, 019d, 32w, 6c, 11	false	false	0.99
25	1130, 020d, 48w, 77c, 11	false	false	0.99
26	0486, 011d, 28w, 26c, 08B	true	false	0.77
27	0454, 004d, 8w, 46c, 08B	false	false	0.55
28	1752, 009d, 15w, 61c, 17	false	false	0.99
29	0454, 004d, 7w, 51c, 08B	true	true	0.99
30	0454, 025d, 37w, 25c, 08B	true	true	0.97
31	0281, 008d, 22w, 56c, 02	true	false	0.65
32	0910, 012d, 25w, 28c, 07	false	false	0.82

33	1562, 003d, 7w, 43c, 17	true	true	0.97
34	1562, 025d, 36w, 19c, 17	true	false	0.86
35	0860, 001d, 25w, 28c, 06	false	false	0.61
36	0484, 012d, 27w, 28c, 08B	false	false	0.54
37	0430, 008d, 17w, 66c, 04B	false	false	0.94
38	1477, 014d, 26w, 24c, 15	true	true	0.77
39	1752, 007d, 16w, 67c, 17	false	false	0.54
40	0325, 025d, 36w, 19c, 03	false	false	0.99
41	0610, 025d, 31w, 19c, 05	true	false	0.82
42	0281, 008d, 17w, 66c, 02	false	false	0.98
43	1752, 006d, 17w, 44c, 17	false	false	0.76
44	0281, 018d, 42w, 8c, 02	false	false	0.99
45	1153, 018d, 42w, 8c, 11	false	false	0.95
46	0820, 016d, 41w, 9c, 06	false	false	0.98
47	1130, 012d, 28w, 28c, 11	false	false	0.99
48	1153, 008d, 14w, 63c, 11	false	false	0.99
49	1750, 022d, 34w, 75c, 08B	false	false	0.98
50	0820, 019d, 44w, 6c, 06	true	false	0.90

The LSTM network is trained using an optimization process that requires a loss function to calculate the model error. The loss function allows to faithfully summarize all aspects of the model down into a single number in such a way that improvements in that number depict a better model. Figure 3 visualizes the loss function and Figure 4 presents the accuracy of the training and validation data for the final model. The final LSTM model achieves an average loss function of 0.0376 on the validation data and a validation predictive accuracy of 0.87. Figure 4 shows the learning curves, exhibiting how the model learned and suitably fit the training data set. These results align with the loss function we obtained on the testing data, which means our final model generalizes well on new data.

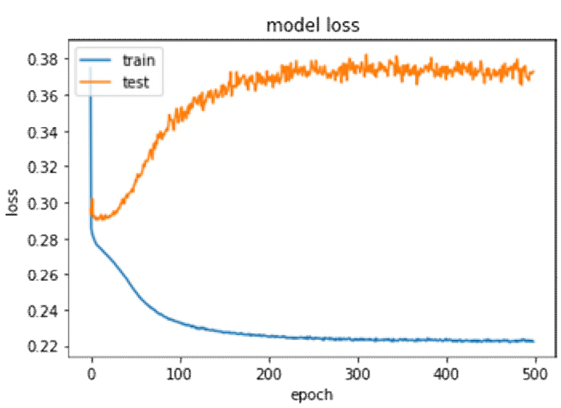

Figure 3. Loss function in training and validation phases by epoch.

V. RELATED WORK

Crime as a problem has both spatial and temporal dimensions. The work by Catlett et al. [17] explores the use of spatial analysis and auto-regressive models to automatically detect high-risk crime regions in urban areas and to reliably forecast crime trends in each region. The algorithm result is a spatio-temporal crime forecasting model, composed of a set of crime-dense regions with associated crime predictors, each one representing a predictive model for estimating the number of crimes likely to occur in its associated region. Also, in [18], the authors propose the use of deep learning for the prediction of hourly crime rates. In particular, their model is used in spatio-temporal problems, like crime forecasting. They detected that future crime rates depend on the trend set in the previous week, the time of day and the nearby events, both in space and in time. For each one of these contributing factors, they use a separate model that offers a prediction based on indicators of a weekly period, a daily period and an hourly period, respectively. The outputs of the 3 models are combined to form a common prediction.

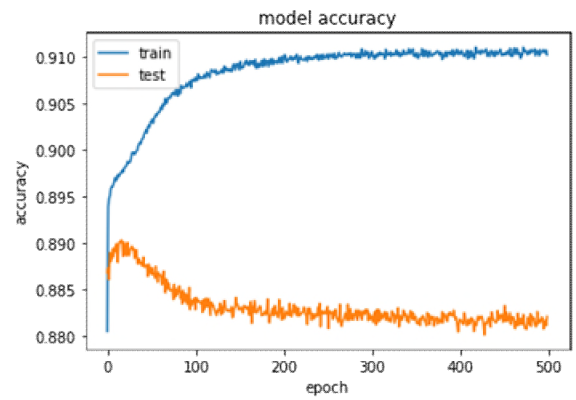

Figure 4. Accuracy in training and validation phases by epoch.

In [19], a system for the visual analysis of multidimensional data on the macroscopic and microscopic levels to show trajectories of crime based on their spatial and temporal characteristics is presented. The system incorporates a novel algorithm for the crime trajectory segmentation and uses LSTM network, generating trajectories from heterogeneous data sources, such as open data and social media, with the aim to report incidents of crime. In [20], a neural network structure for crime prediction and the appropriate inputs for crime prediction are performed through Gram-Schmidt orthogonalization for the selection of network inputs and Virtual Leave-One-Out test (VLOO) for the selection of the optimal number of hidden neurons. Spatio-temporal distribution of the hot-spots is conducted and a methodology is developed for short-term crime forecasting using the LSTM.

In [21], a context-aware attention framework is presented based on LSTM to accurately predict the amount of unrest events news. The social event prediction model consists of three parts: 1) the LSTM encoder, to get the hidden representation of the input sequence, 2) the attention layer, to automatically learn the weights of the hidden representations, and 3) the context-aware fully connected layer used to combine near historical target data and the weighted representation vectors. In [22], a crime prediction framework based on deep neural network that uncovers dynamic crime patterns and carefully explores the evolving inter-dependencies between crimes and other ubiquitous data in urban space was developed. The model enables predicting crime occurrences of different categories in each region of a city, embedding all spatial, temporal, and categorical signals into hidden representation vectors.

VI. Conclusion

The advances in Information and Communications Technologies and the excessive use of smart devices have produced a massive generation of data. This way, IoT technologies and their implementation on the smart cities have caused a growing need for data analysis and big data analytics.

This paper investigated the effectiveness of LSTM neural networks based deep learning approach for predicting the future class labels of a crime incidents instance. To evaluate the predictive performance of our method, we use a data set that collects the historical information of crime indices in a smart city. These data are generated, in most cases, by IoT devices and managed by an information system of the police department. Before applying the LSTM model, we used a pre-processing and categorization of the data. Next, we designed and trained a neural network model in order to select the model that presents the best performance. This process is described by the proposed methodology, which guides the process of preparing input data for the LSTM neural network and its implementation.

From the original data set, 80% of the instances were used for the training stage of our model, and the remaining 20% for the validation stage of the model. The instances used in the training stage were selected by a random method automatically. Our deep learning approach achieves high performance in the final model with 87.84% accuracy based on the validation data. Furthermore, the final LSTM model achieves an average loss function of 0.0376 on validation data, using 20% of the data set for the testing stage.

The research objective was to examine the feasibility and impact of applying the proposed approach to class prediction. The experimental results suggest that the proposed method achieves good results on a big data set.

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