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PhD:

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DOCTORAL THESIS

Research on location based on intelligent technologies in transport and its management

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CONTENT

INTRODUCTION

Transport represents an important area of the social-economic activity due to the fact that it ensures the movement of material resources and people in space, on certain traffic routes, using vehicles or special installations, with the aim of satisfying all the material, intellectual, spiritual needs of the society.

The variable movement of vehicles and people over a period of time represents traffic flow or traffic. All means of transport moving in the same direction, in a traffic system, and for which the points of origin and destination are the same, make up traffic flows.

Although it holds an important position in all human activities, urban transport is currently a delicate problem, difficult to manage for most modern cities. The population of major cities has seen steady growth in recent decades and is expected to continue to do so. Therefore, more and more people rely on public transport for their daily journeys.

Developing effective public transport demand management strategies based on predictive models that use real-time data is a promising approach to adapting existing infrastructure to congested traffic.

Thirty years ago, in the field of aviation, unmanned aerial vehicles / drones were considered devices of the distant future, just like mobile phones. Currently, the use of unmanned aerial vehicles has become a solution for solving many problems of contemporary society.

The civilian use of unmanned aerial vehicles is evident in the field of civil protection, service provision, but also in the field of scientific research. Although the benefits of using these devices are immense, society is concerned about privacy and personal security, so questions of safety, reliability and regulation still remain in the field of using unmanned aerial vehicles.

The original experimental research materialized through an patent and an patent application, through field tests, but also through the 5 solutions developed based on specialized literature.

This PhD thesis is divided into 7 chapters and it is organized as follows: introduction, theoretical study (chapters 1, 2 and 3), experimental research (chapters 4, 5 and 6) and chapter 7 containing general conclusions and future research directions.

Starting from the field of the doctoral program – Engineering and Management, the main objective of the doctoral thesis is innovation in the management of road transport and air transport.

The aim of this doctoral thesis is to develop innovative solutions in the field of road and air transport, so as to ensure a high level of quality of life, personal safety and security.

PART I – THEORETICAL STUDY

CHAPTER 1 – THE CONCEPT OF QUALITY IN PUBLIC TRANSPORT AND AIR TRAFFIC MANAGEMENT

1. The concept of quality in urban public passenger transport

International standard ISO 8402 - *Quality management and quality assurance. Vocabulary* - clearly establishes the terms, definitions and concepts applicable to quality. According to this standard, quality represents a set of properties and characteristics of an entity, which gives it the possibility to satisfy both expressed and implicit needs.

Another standard that introduces quality management systems is ISO 9000:2000 - "Quality management systems". Fundamental principles and vocabulary”.

This standard presents the most important principles of quality management systems, including the vocabulary for them, the concept of quality being defined as follows: *"the extent to which a set of intrinsic characteristics meet the requirements"*.

A series of basic criteria define the quality concept of public urban transport, among them there are: the level of expansion of the transport network, compliance with travel schedules and the punctuality of vehicles, the quality of the information provided, the speed of the means of transport and the duration of the journey, the comfort and safety of passengers both in the waiting stations and inside the means of transport, the level of cleanliness in the waiting stations and inside the means of transport, the degree of diversity of the services offered, facilities granted to people with disabilities, different payment methods, etc.

1.1.1. Internal and external factors influencing quality

According to specialists in the field, organizations constantly interact with the environment in which they operate.

The main components of the environment that influence quality are [6]: the environment / factors of outlets and customers, the environment / technological and technical factors, the environment of suppliers, the competitive environment, the legal environment, the economic environment, the educational and human resources environment, the environment socio - political - cultural.

1.2. The quality of road transport services

Currently, it is considered that there are two main elements with the help of which both performance in transports and its quality are evaluated, as follows:

- the performance of the organization providing transport services;
- the degree of travelers' satisfaction with the service offered (according to some authors "travelers' perception").

1.3. Quality assessment models and techniques in the field of public transport

Currently, in the specialized literature, there are a multitude of models and techniques for studying the quality of public passenger transport services. All these methods are based on analyzing the perception of public transport by its users.

Some scientific studies divide these techniques for assessing the quality of services in public passenger transport into two categories [8]:

- Analysis and statistical methods, which have the role of estimating the individual aspects of the services offered, the relationships between them and the degree of user satisfaction in general. Thus, the Kano evaluation method (Kano Evaluation Table) highlights a set of indices necessary for quality evaluation: Must-be, Attractive, Indifferent, One-dimensional, Questionable, Reversel [9].
- Estimation through the economic modeling process of some coefficients, through linear and non-linear regression models. For example, within the SEM model (Structural Equation Model) [10] any random component (criterion of quality) is considered identical and independent distributed so that the most conclusive results can be obtained.

1.4. The urban transport system

Regardless of your preferred type of transport, private or public, all modes of transport have advantages and disadvantages. However, there are situations in which people prefer public transport, to the detriment of the car, for several reasons: the lack of their own car and low income, the short distance from public transport stations, the active person, does not have long distances to travel and walks on foot with pleasure, aversion to road traffic.

In addition to the subjective reasons that influence the decision of people in choosing a certain mode of urban transport, there are also a number of external factors that play an important role in the choice of the mode of transport: dependence on cars, traffic congestion, urban expansion, pollution, traffic safety.

The performance of a road transport network, per vehicle, can be characterized by several factors: total travel time (h), total distance to be traveled (km), total delays (h) or average delays per vehicle (s), speed average travel (km/h), average number and times of stops for each vehicle, etc.

Over time, many efforts have been made to solve urban transport problems in many countries. The developed strategies aimed at: expanding the existing infrastructure, increasing the number of traffic signals, efficient management of traffic, especially the flow of vehicles, increasing the quantity and quality of traffic information, road taxes, subsidies to make public transport more attractive, a better integration of urban transport planning with land use [14].

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1.5. Public transport in Bucharest

At the end of 2020, the public passenger transport infrastructure in the city of Bucharest reached a total of 1,585 means of public transport (1,124 buses, 181 trolleybuses and 280 trams) due to the introduction of new hybrid buses [16].

Regarding underground public transport, although the subway network represents only 4% of the length of the capital's total public passenger transport network, under normal conditions, the Bucharest metro transports approximately 500,000 passengers every day and more than 15 million travelers in a month.

In Bucharest, as well as in other large European cities, as a consequence of the increase in living standards, there has been a significant increase in the number of registered cars. Obviously, the main consequence was an increase in traffic jams that indirectly led to a decrease in the number of public transport users.

Thus, as can be seen from the following figures (fig. 1.3., fig. 1.4.), the degree of motorization in Bucharest, as well as the percentage of trips made with private transport, is one of the highest in Europe.

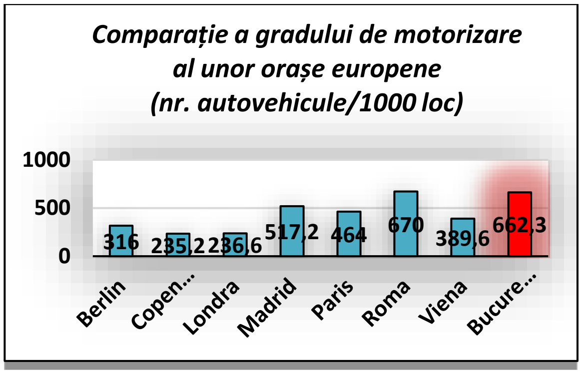

Fig. 1.3. The degree of motorization of some European cities - comparison. Sources: Associazione Transporti ASSTRA - su dati raccolti tramite i questionari; https://data.gov.ro; http://www.insse.ro

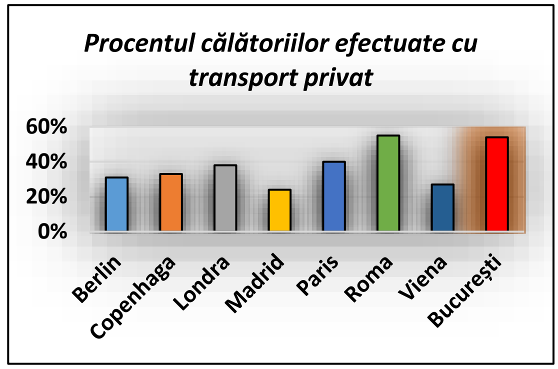

Fig. 1.4. Percentage of trips made with private transport. Sources: Associazione Transporti ASSTRA; http://www.insse.ro

It is well known that the road infrastructure in Bucharest is not organized in full harmony with the current traffic, for this reason, any trip with a certain means of public transport, especially during peak hours, is a real adventure, sprinkled with countless traffic jams and, last but not least, with disastrous effects on the environment.

2. Air traffic management

Air Traffic Management (MTA) involves the existence of 3 distinct activities:

- *Air Traffic Control (ATC)* represents the activity by which aircraft are directed by the controllers in the control tower, as they fly between airports;
- *Air Traffic Flow Management (MFTA)* is an activity that takes place before the aircraft takes off. Each aircraft using air traffic control flies in accordance with a flight plan that has been sent at least 30 minutes before take-off;
- *The aeronautical information service (SIA)* involves the creation and distribution of the necessary information for all airspace users, such as: information about the safety of the airspace area, navigation, technical, administrative information, but also legal aspects regarding the use of the airspace and their updates.

The emergence of unmanned aerial vehicles (UAVs), drones, plays an important role in the civil field. Thus, civil unmanned aerial vehicles differ from military ones, they have the possibility to fly for several tens of minutes and can be maneuvered both from the ground and from a distance.

The advantage of using these aerial vehicles without an operator, compared to other devices, is reflected in the fact that financial resources are saved, they can be used in and in hard-to-reach areas, in situations where the human factor cannot be involved (fires, areas with difficult terrain accessible, natural calamities etc.). Even if the use of unmanned aerial vehicles in these activities brings important benefits, a major problem currently existing at the international level, as well as at the national level, is the fact that there are no clear legal regulations that can legally frame aerial operations with this type of equipment.

The risks of using an unmanned aerial vehicle refer to national security risks, traffic safety risks (the risk of collision with an aircraft), the crash of unmanned aerial vehicles in a crowded public space, intrusion into private life, assassination of people.

Another major risk is the lack of regulation regarding the age category considered acceptable for the operation of unmanned aerial vehicles.

The concerns of all countries to regulate the use of unmanned aerial vehicles aim in particular to ensure the safety of people who may suffer from the use of this equipment, through measures that guarantee both the safety and the security of civil aircraft flights, as well as the safety of life and people's health, private life etc. On the other hand, it is important to ensure favorable conditions for the users of unmanned aerial vehicles, due to the fact that this technology brings countless gains to those who use it, and it would not be indicated that the use of this equipment is possible with restrictions or too harsh requirements.

In the future, the researchers plan to test several concepts, one of which would be geofencing. This concept involves creating virtual fences within which UAVs can automatically steer around a restricted geographic location, such as an airport.

Another important area of research involves collision detection. UAVs will need to have sensors to allow them to detect and avoid collision with another UAV. Thus, this mode will allow UAVs to avoid any mid-air incidents such as flying above, below, around other UAVs etc.

CHAPTER 2 - THE CURRENT STATE OF RESEARCH IN THE FIELD OF ROAD AND AIR TRAFFIC MANAGEMENT

2.1. The current state of research in the field of road traffic management

Knowing a person's position with an accuracy of a few meters is extremely useful for providing relevant contextual information and services. In the specialized literature, methods, techniques or solutions for monitoring road or air traffic, based on new information and communication technologies, are presented.

2.1.1. Combined location algorithm based on Bluetooth and Wi-fi

In the specialized literature, the methodology for obtaining a suitable propagation model for Bluetooth (BT) is presented, in order to obtain a more accurate distance measurement together with a combination algorithm with Wi-Fi, for determining the position of a user in an indoor environment [23, 24].

Altini et al. [26] propose a method that considers the placement of Bluetooth transmitters according to a known distribution and considers that a previously trained neural network is required to calculate the position.

In another scientific research [27] it is proposed to use RSSI information between several fixed wireless beacons, so as to improve the reliability of a Bluetooth positioning system. The information obtained in this way is used to calibrate the responses of the sensors. Also, position fingerprinting systems are other feasible solutions, useful for indoor positioning, according to the specialized literature [28, 29].

Another approach proposed in the specialized literature [30] refers to the availability of signals in the indoor environment, signals that can be obtained from Bluetooth, Wi-Fi and GPS sensors. The proposed method is based on the prior existence of RSSI (Received Signal Strength Indicator), Bluetooth and Wi-Fi radio maps. The method also assumes a predetermined distribution of Bluetooth and Wi-Fi stations.

In the specialized literature [31], however, a very simple method is also proposed, which involves obtaining good position estimates, using GPS as the main source of information.

2.1.2. Derivation of an RSSI model

Permanently, it has been tried, and it is still being tried, to develop a model that allows the approximation of a user's position with high precision.

As observed in the research, radio frequency propagation models follow a logarithmic behavior, and in order to evaluate the correctness of the proposed model, it is necessary to apply some quantitative and qualitative tests.

The coefficient of determination (R^2) is proposed as a criterion to find the correlation between the true values of a variable and its approximate estimates, with values closer to 1 indicating a better model fit [32].

From the previously collected data, three models were acquired. After comparing the three models, using the coefficients of determination of each model as an indicator of the model that best fit the data, the third model was chosen to be implemented.

2.1.3. Model used to measure Wi-Fi signals

In the specialized literature, among the many models and their equations, both empirical and non-empirical for radio frequency propagation, there are models specifically designed for indoor environments such as: Mootly-Keenan [33], model MWF [34] și Free-Space Path Loss (FSPL).

The Free-Space Path Loss model shows the signal strength loss of an electromagnetic wave that would result from a line-of-sight (LOS) path. There is no reflection or diffraction. FSPL is the function of frequency and distance between transmitter and receiver [35].

2.1.4. Combined Wi-Fi-Bluetooth based positioning algorithm

The proposed algorithm is based on multilateration and to estimate the position of the individual it needs the coordinates of at least 3 devices placed near the receiver, with respect to an origin that can be chosen randomly (for example, the entrance door of the house) and the frequency of the WiFi stations.

The models obtained for Bluetooth and Wi-Fi in the previous sections (2.1.2. and 2.1.3.) were used to calculate the distance from the receiver to each of the available transmitting devices.

2.1.5. Location simulations based on trilateration and RSSI

In the specialized literature [37] a method of positioning the individual is proposed that combines WLAN and Bluetooth technologies, based on the trilateration technique.

The most suitable scenario for localization accuracy has been demonstrated even in the situation where a high signal attenuation parameter is used. Trilateration is a method that calculates a node position by the intersection of 3 circles. The position of the three reference nodes, as well as the distance to each of them, must be known. This experimental research represents an important achievement in high-precision localization in the indoor environment.

2.1.6. WLAN (Wireless Local Area Network) and Bluetooth location systems

One of the techniques proposed in the specialized literature is multilateration. In this case, an RSS reading is simulated to determine the distance to the WLAN base, which base is taken together with a signal attenuation parameter, introduced precisely to simulate different environments and signal losses due to the simulated structure.

This technique does not require specialized hardware, so the simulation can be performed without problems. In the specialized literature, these methods are used to develop systems based exclusively on Bluetooth, using RSSI [39, 48, 49].

2.1.7. WLAN, Bluetooth and Fusion

The biggest problem in positioning systems is that not always 3 transmitters are visible and have a sufficient and clear signal [17]. To solve the problem, it has been proposed to fuse different types of signals in order to complete the localization, proposals [37] combining the GPS system with WLAN and fusing signals from WLAN and Bluetooth [46].

The proposed method, described in the specialized literature, considers that, due to the fact that trilateration is functional for WLAN and Bluetooth-based localization systems, it is possible to combine them to obtain better results, compared to their independent use.

2.1.8. Propagation attenuation models for Wi-Fi signals

In the scientific literature, some authors consider it acceptable to model propagation attenuation for Wi-Fi signals using the concept of free-space signal strength (FSPL), since the direct wave makes the most significant contribution to the received signal [50].

In an environment such as public transport, the propagation conditions of radio signals are relatively weak and undergo large dynamic variations, due to the presence of buildings / walls, people, surrounding RF (Radio frequency) devices and other factors. A specific phenomenon in a typical tunnel is multipath propagation, which can lead to both destructive and constructive interference at the receiver location. Common sources of multipath propagation for these indoor areas are the very walls of tunnels or stations, but also the terrain itself.

A well-known model describing this effect is the so-called two-ray attenuation model [52]. Other factors that limit the usability of radio signals include interference with other signal sources, thermal noise, etc. Currently, there are several signal propagation and loss models: Okomura model [53], Hata model, Akeyama correction, Sakagami – Kuboi model, Xia model [54], Erceg - Greenstein model (Stamford University Interim) [55], propagation attenuation model with the logarithm of the distance (Rappaport), Longley - Rice radio propagation model, or irregular terrain model, geometric diffraction theory [56], PCS extension for the Hata model [57].

2.2. The current state of research in the field of air traffic management

Currently, commercial unmanned aerial vehicles are a market product because the control and operation technologies of these unmanned aircraft are cheap, widely available, and characterized by rapid development [58].

The study of acoustic signatures of commercial unmanned aerial vehicles has highlighted the possibility of developing sound analysis systems for monitoring by using functions to identify the sounds produced by these UAVs [61, 62, 63].

In the scientific literature, Mezei [64] proposed an acoustic detection for monitoring unmanned aerial vehicles using the audio fingerprint correlation technique. Also, Souli [65] made an environmental sound spectrogram together with a SVM (Support-vector machines) classification algorithm, based on patch spectrum reassignment.

This research proposed an inexpensive and portable detection system that would extract and classify in the time and frequency domain the spectral characteristics of sounds, thus determining whether or not there is a UAV nearby.

The most difficult problem in the verification and classification of acoustic signals is the normalization of the intra-sound similarity variation. Normalization methods based on likelihood ratio and normalization methods based on posterior fitting have been described in the literature. However, in order to reduce the computational cost of the normalization term, the "cohort method" or "universal model" was proposed.

CHAPTER 3 - APPLICATION OF ARTIFICIAL INTELLIGENCE SYSTEMS IN TRANSPORT MANAGEMENT

3.1 Intelligent transport systems

Artificial intelligence is prominently present in economic activity, and nowadays we encounter it more and more in intelligent transport systems.

Currently, artificial intelligence systems (AIS - Artificial Intelligence System) are used more and more with the aim of automating the decision-making process for various economic fields.

Intelligent transport systems represent the application of electronics, IT and communications in transport. The main objectives of these systems refer to the reduction of negative results in the transport activity (loss of human life and material, accidents, pollution, additional costs) and to the efficiency of this activity.

Currently, many ITS (Intelligent Transport Systems) applications use solutions that are based on artificial intelligence (AI – Artificial Intelligence), Big Data, Data Mining, but also intelligent technologies. This means that the term "Intelligent Transport Systems" represents the technologies used and not marketing tools.

Modern transportation systems include a host of ever-evolving technologies and applications, starting with real-time traffic information, electronic tickets, and continuing with automatic passenger counting, with artificial intelligence-based traffic forecasts.

The transformation of a city's transport network into an intelligent system offers benefits on several levels, such as: increased income, active contribution to increasing the standard of living in the city, positive perception of citizens on the concerns of the authorities for good governance - catalyst for an economic life healthy cities -, improving the efficiency and operational performance of the transport network - especially due to reduced costs, increased passenger mobility and comfort, increased use of the transport system.

Predictive methods can also be used for urban transport planning, their results contributing to the measurement of decision-making performance in traffic.

In recent years, there has been a growing interest in using game theory algorithms combined with intelligent agents to develop software systems to assist in decision making and in the development of agent-based management systems. Prediction and decision theory is based on mathematical algorithms for making decisions and generating strategies that can be applied when the outcomes of potential actions are unknown. Game theory was developed long before the concept of "intelligent agent" appeared. Intelligent agents are examples of software applicability for decision makers that can combine classical decision-making theory with artificial intelligence algorithms. Managers of intelligent transportation systems can use and apply game-theoretic methods developed on the basis of intelligent agents to solve traffic problems.

The specialized literature presents the use of IoT (Internet of Things) and blockchain (Blockchain) technologies together with applications developed for supply chain management, technologies that have a major impact on road, maritime and air traffic management, in tracking goods as well as supply (efficient inventory management, reduction of losses in the supply chain, etc.). The advantages of using these technologies in the transport industry (road, sea, rail, air) consist in facilitating the establishment and planning of routes, in the automation of drivers' tasks, in the reduction of bureaucracy, of costs due to the reduction of the number of people involved in the monitoring process.

Starting with document management and shipping tracking, ledger technology can act as a communications network for the Internet of Things by facilitating both radio frequency identification (RFID) and the use of quick response (QR) codes and tags. Network data blocks allow the storage of large amounts of data in a secure and decentralized manner, thus ensuring fast data processing in a short time.

Currently, the increasingly frequent occurrence of moments of panic during mass events has led to the development of research in terms of studying the impact of panic on crowd dynamics and simulating the flow of people in panic situations. Thus, the social force model is extended by a model of people's route choice behavior, so that a solution for urban traffic planning is possible [67]. Its corresponding forces can be modeled for each individual and represent a different variety of behaviors that can be associated with panic situations [68], such as danger avoidance, crowding and pushing [69].

In crisis situations, Deep Learning networks and Voronoi diagrams can be used to detect the escape route from a crowded area. The use of neural networks involves training a neural network that allows accurate detection of roads by analyzing images from an event. Recent advances in aerial imaging technology make it possible for unmanned aerial vehicles / satellites to provide high-resolution imagery that can be easily interpreted by road users.

Thus, the fundamental role of the decision-making technical support system consists in providing, in real time, with maximum security, relevant information that allows traffic participants to use it to achieve their goals.

In recent years, in addition to the problems in road traffic, we can also discuss the problems that arise in air traffic. Since the capacity of the airspace is limited [70], and the increase in the level of use of unmanned air traffic can lead to insecurity and potential critical situations, it has become necessary to develop some architectures of unmanned air traffic management systems (UTM - Unmanned aerial traffic Management system) to ensure the maximization of the use of this space [71].

Fuzzy logic involves replacing Boolean variables. Thus, fuzzy logic, which is based on the theory of fuzzy sets, allows the linguistic description of the command, operation and control laws of a system. Due to its ability to gradually present information in a way familiar to human thinking, fuzzy logic is an important tool for integrating intelligence. Experimental research on the use of fuzzy logic to track a target's trajectory has highlighted the importance of this method in unmanned air traffic management [73].

3.2 Algorithms used in the analysis and filtering of data captured from intelligent transport systems

3.2.1 Extracting information from data (fig. 3.3.)

Schematically, the process of extracting information from data collections (Data Mining) presents three defining steps:

- *"Exploring data" - involves "cleaning" them, modifying data, sorting data subsets, sorting features, for cases where there are a large number of variables etc.;*
- *"Building the model and validating it" - involves estimating different models and choosing the model that presents the best forecast performance;*
- *Applying the model - obtaining correct predictions / estimates for the researched problems.*

3.2.2 Problems that can be solved with knowledge extraction from data

As a rule, when using knowledge extraction methods from data to solve concrete problems, the typology of these methods must be taken into account, as follows:

- Predictive methods – which use a certain amount of the total of existing variables with the aim of forecasting some later, unknown values of other variables (classification, regression, detection of deviations etc.);
- Descriptive methods - discover certain patterns in the data, easily interpretable by the user (clustering, association rules, sequential patterns, etc.).

PART II EXPERIMENTAL RESEARCH

CHAPTER 4 - ROAD AND AIR TRAFFIC MANAGEMENT SOLUTIONS

4.1. Development of a road traffic control application (values generated by Count Objects)

Based on the data from the specialized literature, the first solution developed within the Department of Remote Controls and Electronics in Transport of UPB takes into account the fact that, currently, artificial intelligence is found prominently in economic activity, but also in intelligent transport systems.

The classical approach refers to the fact that semantic segmentation is based only on the color information extracted from images, so using depth maps that were obtained from disparity maps brings important advantages in terms of segmentation. Segmentation is the classification of images at the pixel level.

Cars, pedestrians and traffic objects are limited by spatial and geometrical restrictions. These constraints are defined and incorporated into the perception solutions as additional context channels alongside the filtered feature channels.

This allows classifiers to learn the context for different object types or semantic classes. Context features can speed up the prediction process.

In the case of soft-cascade decision trees, the prediction stops when the intermediate prediction score falls below a certain threshold [112]. Context features can stop prediction at an early stage when the context is not suitable for a semantic class.

The following contexts were used for the semantic segmentation experiments:

- Spatial 2D: horizontal and vertical position in the image;
- Spatial 3D: 3D x, y, z position, dense interpolated representation from stereo video cameras;
- 3D Size: The width and height in 3D of the super-pixel groups.

To generate semantic segmentations, an individual binary pixel classifier was trained for the respective semantic class. Also, the use of multi-radius classification features, extracted from feature channels, was proposed. Next, individual pixels were classified using the surrounding pixel values from the feature channels. In this way, the closest points can capture the local structure, while the far points capture the context.

The methodology proposed in this research consisted in the application of image processing methods and polynomial prediction analysis. Following their application, it was found that the results contribute to the measurement of road traffic prediction performance.

The research conducted highlighted that the methodology based on the AI-oriented classification and prediction approach can be implemented to measure, evaluate and improve traffic using STI strategies. The practical aspects addressed in this research are related to the identification of the most problematic obstacles encountered in the implementation of performance management in STI, by using a new methodology based on artificial intelligence [114].

4.2. Game Theory in Decision Management: Using Game Theory and Intelligent Multiagent in Transportation Planning

The method proposed in the research is based on game theory and the implementation of Intelligent Multiagent Systems (SMA) [120]. Thus, according to the method, each agent has an associated utility function. The values of this function are represented in a matrix that is known by both agents involved in the negotiation. Each agent also has an alternative solution that will maximize its utility. Although the method based on game theory is simple, it has important restrictive regulations that make it difficult to apply it in practical situations.

The proposed transportation planning algorithm works for a large number of people, each person with a measurable level of "fitness" using a metric defined by the model builder (figure 4.3).

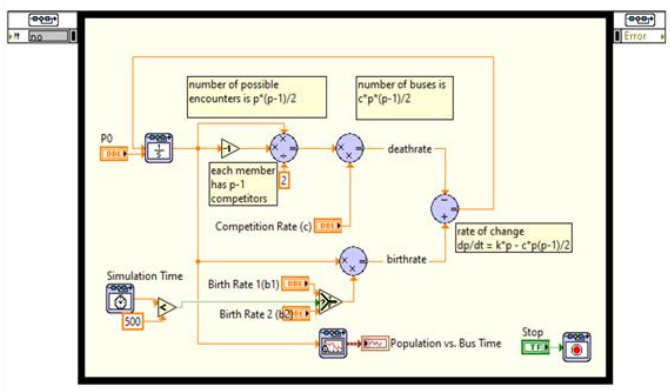

Fig. 4.3. Game theory used for bus destination selection [120]

The most representative individuals are "reproduced" by breeding with other individuals who are adapted to the process, and their breeding results in offspring that have characteristics taken from both parents. Breeding over several generations will lead to a state of population mobility as it evolves and adapts to the environment. In the case of neural networks and genetic algorithms, software developers must take a decision about the conditions imposed on the development model.

Thus, in the case of models based on genetic algorithms, it can be considered that a single agent can represent the entire population. The genetic algorithm will become a "black box" that will be used by the agent to be able to learn and adapt to the environmental conditions imposed by the developer. Alternatively, each individual can be programmed as an individual agent, and the result will be a population of intelligent agents interpreted as a whole in the evolutionary process.

Similarly, each agent or groups of agents can be programmed with neural networks. Each developmental environment as well as the society can be represented as a single neural network, each neuron being assimilated to an agent (it is difficult, however, to build all the attributes of the agent for this situation).

4.2.1. Implementation of SMA algorithm and game theory for urban transportation

An efficient way to develop agent-based models involves the use of a manufacturing system algorithm.

By using a production system algorithm, it is easy to build and introduce into the community intelligent reactive agents that can respond with actions to external environmental stimuli.

In figures 4.4 and 4.5. production algorithms developed on the basis of real-time data correlated with historical data obtained in different time periods (morning time slot, evening time slot) are presented, which can be used to implement urban transport planning management.

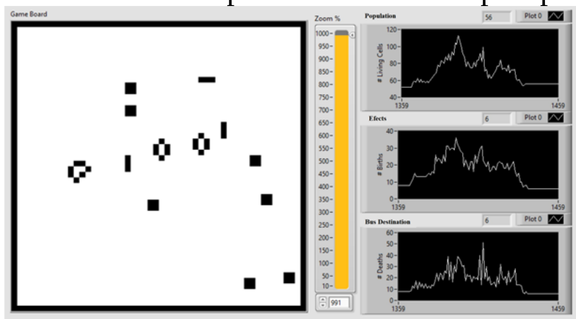

Fig. 4.4. Adaptive bus destination development algorithm (for Morning Time Slot)

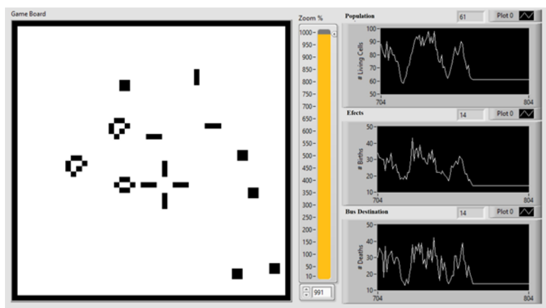

Fig. 4.5. Adaptive Bus Destination Development Algorithm (for Evening Time Slot)

From the study, it emerges that traffic management is based on the estimation of the parameters of the evolutionary game matrix, by using different implementation methods with intelligent agents [120]. The main result of this research is the application of game theory and intelligent agents in the complex process of traffic planning. Thus, it was presented how real-time data can be correlated with historical data obtained in different time periods.

4.3. IoT Technology and Supply Chain Management

The Internet of Things (IoT) originally appeared as a concept of direct interconnection, through the Internet, of several devices, equipment, tools, household appliances, mobile vehicle models that can communicate with each other, but also with fixed infrastructure [121]. In addition, the "Internet of Things" can include both physical objects (hardware) and software objects (object-oriented programming) but also virtual objects ("avatars" of things).

Ledger technology is a system of recording information in such a way that it is difficult or impossible to change, hack or cheat the system, it is an incorruptible digital ledger of transactions that is copied and disseminated throughout the network of computer systems in the ledger.

As for the advantages for the transport industry (road, sea, air), they are as follows: it reduces red tape, reduces costs and human administration of the process, facilitates the establishment and planning of routes and automates the tasks of drivers.

Ledger technology can also be used to simplify the supply chain, thereby reducing human interaction, increasing the speed of supply management and enabling communication between vehicles.

Starting from document management and transport tracking, ledger technology can act as a communication network for the Internet of Things (IoT) thus facilitating the use of radio frequency identification (RFID), the use of quick response (QR) codes and tags.

Intelligence and decision-making, in an IoT-based multimedia system, are embedded in sensors. Similarly, a Cloud server, through the use of artificial intelligence algorithms, is able to maintain, develop and execute various services, thus providing large computing and data storage resources. This type of approach provides users with the ability to monitor and control devices from anywhere in the world [129].

Currently, IoMT communication provides global access to multimedia devices (for example: cameras or mobile phones), through a single IP address, in the same way as connectors or other devices connected to the Internet.

By miniaturizing the size and cost of connected multimedia devices in IoMT networks, their widespread use has been promoted. These devices will be able to make ad hoc connections with all the devices in the network, through registry technology.

In this new configuration, traffic monitoring systems will move to a new level, and based on deep learning software applications for object detection and recognition, they will be able to predict traffic flows, thereby transmitting traffic flow control commands to the network and travel.

Multimedia content transmitted from the sensor to the Cloud server with processing and storage applications can generate traffic management restrictions that are essential for real-time transmission of continuous video streams and can introduce acquisition delays or interruptions, which can cause difficulties major in the road traffic monitoring process. These difficulties can lead to a malfunction of software applications, developed with artificial intelligence algorithms, for the detection and recognition of objects (cars, pedestrians, face detection and recognition, car tracking). For example, users can be allowed to simultaneously access sensor data remotely, rulesets can be implemented to control the automatic operation of cloud actuators for identity verification and policy management as a service, thus enabling processing and real-time analysis for video surveillance etc.

4.3.1. Research Methodology: Cloud IoT Integration Through Real-Time Communications Web Registry Technology (Web-RTC)

WebRTC (Web Real-Time Communications) refers to a "collection of communication protocols and application programming interfaces" (API- Application Programming Interface) that provide the real-time communication process using peer-to-peer (P2P) connections) [130]. In this way web browsers are authorized to send and receive information in real time, from and to other users' browsers (the condition for doing this is the new performance in terms of the speed of IP communications).

LabVIEW and Matlab are software development environments for object recognition and classification solutions using neural networks and deep learning algorithms [132].

The LabVIEW workflow involves the following steps (Figures 4.8. and 4.9.): object recognition and classification based on a previous model, transformation of car and pedestrian data for analysis using neural networks, object representation on datasets 128 - dimensional, using deep neural networks.

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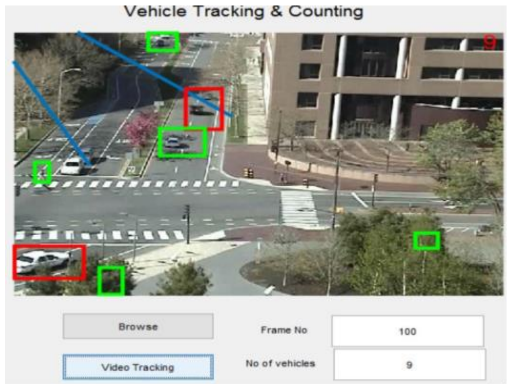

Fig. 4.8. Machine and person recognition using deep learning neural networks

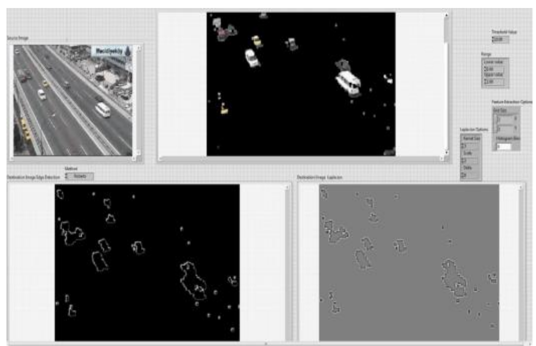

Fig. 4.9. Vehicle motion detection by highway detection and analysis using IoMT

A primary advantage of using LabVIEW in developing neural network software applications is the ability to import extensive libraries of objects [134]. Thus, the training database for object recognition and classification will be installed on Cloud servers and will be able to be accessed and used in data processing and object recognition, using software applications developed within the Department of Remote Controls and Transport Electronics of UPB.

In conclusion, it can be seen that nowadays the supply chain management used in the field of transport has developed a lot, from manual operations that generated prediction risks, to automatic management in real time, which is no longer a generator of risk.

Starting with the use of simple goods identification devices and reaching a complex architecture that works in an intelligent system, IoT has revolutionized the transportation and supply chain industry, starting with sourcing, product selection and delivery to users.

4.4. Strategic decision support - Integrated system of support and management of crisis interventions

4.4.1. Agent-Based Modeling and Simulation of Crowds in Panic Situations

Research work has been based on an agent model to describe the behavior of individuals in panic situations and to predict collective human behavior in a high-density crowd [144].

The aim of the research was to introduce a panic parameter to affect agent behaviors, a mechanism for spreading panic in the crowd, and auxiliary states for modeling push/push behaviors that do not belong to the Helbing model [145, 146].

4.4.2. The "push/push" model

"Push" behavior is the behavior by which an agent tries to force, to find a way out of a crowd. Thus, for an agent to be able to push, the planning part must overcome the interaction forces.

To achieve this effect, an integrator will be added to the planning part, thus resulting in a new acceleration equation that can be represented as a proportional integral control (figure 4.13.).

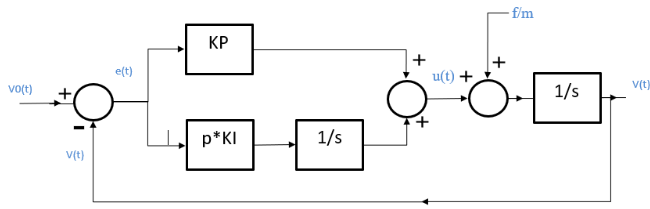

Fig. 4.13. Speed control represented by the proportional values of the integrator.

4.4.3. Panic behavior

Herding behavior is one of the key reasons for modeling panic behavior, in which individuals transfer their behavior to other agents. Each agent has Pi as panic parameter, its value varying from zero to one. The initial value of the panic parameter is always zero, but this value increases due to sources of panic in the environment or can be acquired from the environment.

The pattern obtained in the research depends on the number of agents in the surrounding area and their level of panic [144]. The surrounding area is defined as a circle centered on the agent's position, with radius r_{si}. However, the panic behavior will also depend on the relative distances between the agents. Thus, an agent will be more affected by agents that are at shorter distances.

In the model developed in the research, the integrator will be stopped if the control output $u(t)$ saturates, (figure 4.14.), i.e., it reaches the push limit of the agent.

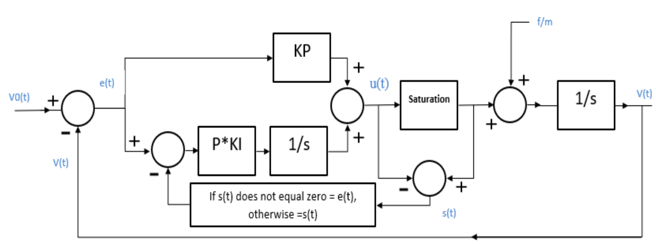

Fig. 4. 14. Control of agent push speed when panic is set.

4.4.4. Escape route detection from a crowded area using Deep Learning and Voronoi networks

The research undertaken focused on training a neural network to accurately detect roads / exits based on the analysis of images from an event. Thus, the experimental research also developed a geometric solution for graph-based community detection, starting from Voronoi diagrams.

This method is used to divide metric spaces into regions (Voronoi cells), around selected points (generating points), as shown in figure 4.15. (map representation of black-red cells). This solution applies to graphs, where all connections have a positive length and the distance between two nodes is equal to the shortest path between them figure 4.15. (green line) [147].

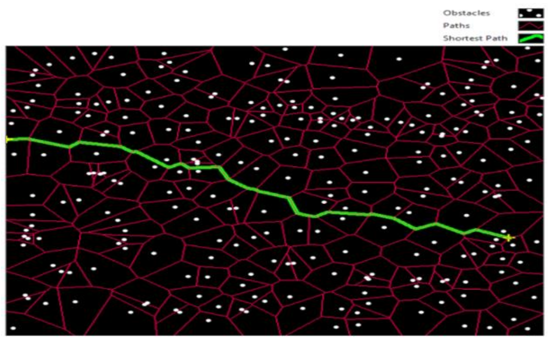

Fig. 4.15. Automatic determination of the escape path (green line) from the event scene (background cellular map) using Deep Learning and the Voronoi algorithm.

The developed algorithm was tested on several real-world networks with different structures and origins, and the results were compared with the results of five other algorithms used at scale.

It was found that the method developed in the experimental research works well for relatively small values of the parameter *r*, and in the situation where we have a pronounced mixture between the groups, the right clusters cannot be identified. In conclusion, it can be said that the fundamental role of the technical decision support system is to provide, in a timely manner, under conditions of maximum security, decisive and relevant information to enable the action forces to use it in achieving their objectives during all stages of the tactical action.

4.5. Contributions to Unmanned Air Traffic Management System Implementation Using Distributed Fuzzy Control

Following the collaboration between the departments of Engineering and Management for Transport and the Department of Remote Controls and Electronics in Transport, the Faculty of Transport within the "Politehnica" University of Bucharest (UPB), a UTM system, based on control with distributed fuzzy logic, resulted [153].

In the research process, the superiority of fuzzy logic over the Kalman filter was demonstrated and a new algorithm for trajectory estimation based on distributed fuzzy control was proposed.

The goal is to characterize the detected object by its position and orientation towards a direction, by means of two fuzzy subsets. It can be stated that the advantages of using a network of fuzzy components do not consist only of the advantages offered by distributed systems. Fuzzy cells have been observed to be easy to configure but at the same time provide high-level functions similar to fusion and decision-making processes. The network also allows components to be added to increase system performance. The added components do not necessarily have to be fuzzy components because the network supports multiple data types.

CHAPTER 5 - INTEGRATED SOLUTIONS FOR ANALYSIS OF DATA CAPTURED FROM INTELLIGENT TRANSPORTATION SYSTEMS

5.1. PART I OF EXPERIMENTAL TESTS

5.1.1. Setting up the test platform [154]

The proposed solution for collecting information about passengers in a subway station and on trains consists in using a concept based on the anonymous detection of the number of Wi-Fi (or Bluetooth) devices carried by passengers.

Metro line M2, Bucharest city - Romania, Unirii station was selected as a suitable environment for the experimental tests (a schematic diagram of the station is shown in figure 5.1.). The reason for this choice was the fact that in this area there is a significant flow of travelers most of the day, and the length of the platform is sufficient to cover all conditions related to remote coverage with Wi-Fi technology.

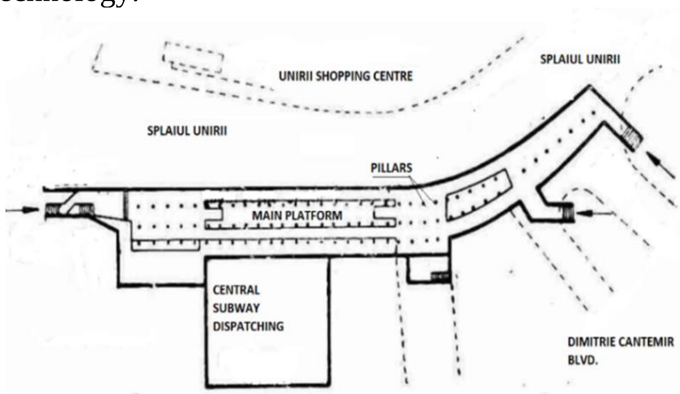

Fig. 5.1. Unirii II, Bucharest

Figure 5.2 shows the concept and figure 5.3 shows the setup of the test area with the location of the access point near the north wall of Unirii metro station. The receiver was then successively placed at different distances from the AP (Access Point), on platform 1, under different conditions: with or without people on the platforms, with or without trains in the station [154].

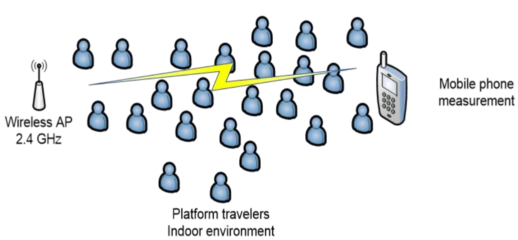

Fig. 5.2. The concept of testing

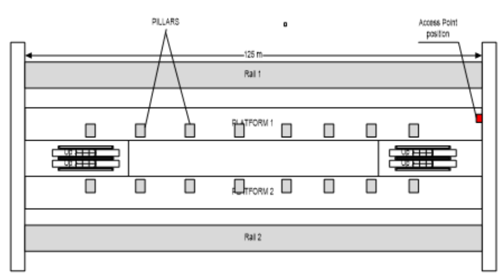

Fig. 5.3. AP location: 1.5 m above the ground, near the north wall

5.1.2. Field test results [154]

The first tests carried out for this project were carried out to determine the variability of RSSI levels and speed, for download and upload at the fixed access point.

RSSI was found to suffer a sudden, relative drop in level within the first 30 meters or so from the radio source, then the level oscillates in the -10 dBm range, centered on -82 dBm, which remains constant over 60 meters from the AP. Respecting the download/upload speed, the same phenomena are observed especially regarding the variation of the upload speed: a rapid decrease in the first 30 meters, then variations around an average of 2.5 Mbps for the next 100 meters, distance from by AP.

A week later, the tests were repeated under the same conditions to determine the constancy of the measurements. Potential sources of interference were the presence of numerous active Wi-Fi and BT devices when subway stations are crowded with passengers. In the next part of the paper, the diagrams will be presented comparatively, in the following conditions: in open space (FOV - Field of view conditions), in the subway station without passengers, in the subway station with many passengers on the platforms.

In Figures 5.7, 5.8, 5.9 it can be seen that the discharge speed has a more abrupt variation in the FOV conditions than in the subway station, which leads to the idea that the station walls behave as a waveguide to some extent. The variation is less abrupt under station (indoor) conditions than outside, and for the first 35 meters it is relatively stationary.

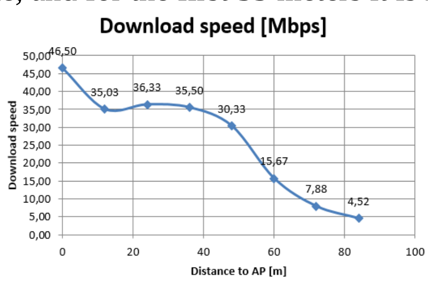

Fig. 5.7. Data download speed variation, in free space

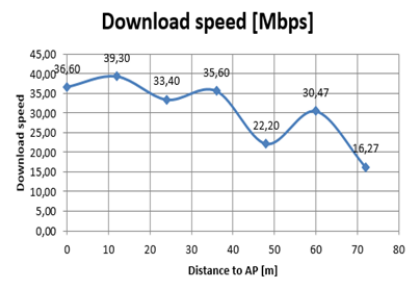

Fig. 5.8. Variation with distance of download speed, inside the subway station, without passengers on the platforms

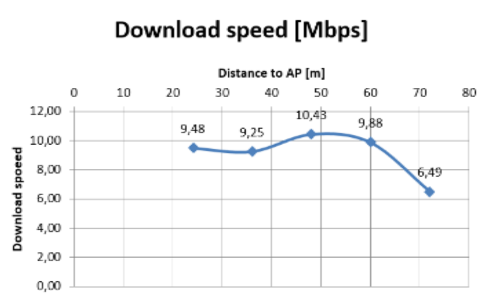

Fig. 5.9. Variation of data download speed with distance, inside the subway station, with passengers on the platforms

However, when many communicating nodes enter the local network, the overall download speed degrades significantly (Figure 5.9), with levels rarely exceeding 10 Mbps. Again, for the loading speed test (figures 10 to 12) the same phenomenon, but at much lower speeds is present in the subway station: compared to the FOV conditions (fig.5.10), the loading speed is less high, but more constant over longer distances (figure 5.11), keeping a constant behavior even with more nodes in the network (figure 5.12).

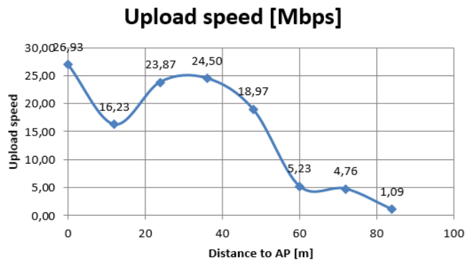

Fig. 5.10. Variation of charging speed with distance, in the open field

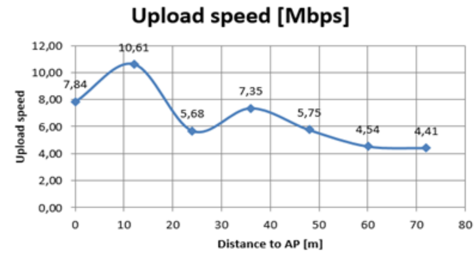

Fig. 5.11. Variation of loading speed with distance, inside the subway station, without passengers on the platform

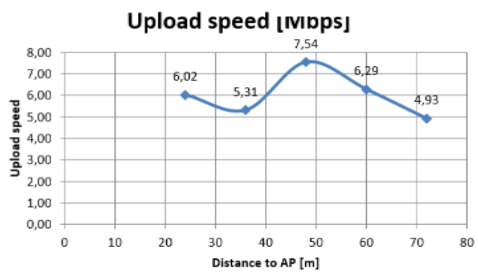

Fig. 5.12. Variation of charging speed with distance, inside the subway station, with passengers on the platform

5.1.3. Conclusions regarding the first part of the tests [154]

The indoor environment creates completely different conditions for the propagation of radio waves, there are some factors that also contribute to the signal propagation behavior, such as the shape, configuration, geometry and materials of the station walls, the presence of pillars, etc. Therefore, a general pattern of signal propagation, valid for all station configurations, is not possible to establish. However, with small adjustments, some of the already existing models seem to obey the signal propagation behavior for these distances.

This first part of the tests proved that it is possible to determine by simply detecting and identifying the MACs of Wi-Fi devices carried by passengers, their flow in metro stations, thus contributing to the collection of information on the level of congestion, route guidance and other services.

5.2. PART II OF EXPERIMENTAL TESTS [156]

These tests are a continuation of the experiments carried out in a metro station to evaluate indoor signal propagation conditions, especially for Wi-Fi channel 1 (2.4 GHz band), as support for an anonymous determination solution regarding passenger flow in similar environments.

To better explore the propagation conditions a set of initial calibration tests were performed in an open field area outside the metro station to evaluate the equipment characteristics. The collected data served as a reference for the measurements performed in the indoor environment. Inside the metro station, the AP was placed next to a wall at one end of the station (figure 5.3), and a mobile phone with dedicated software was placed at different distances from the AP to determine the evolution of RSSI, latency and data transfer speed.

Three scenarios were considered: measurements made in the open field (FOV) - RSSI variation, data speed and latency, indoor measurements for the same parameters, without people on subway platforms (only to determine the influence of the environment geometry: walls, pillars, platforms, etc.), indoor measurements for the parameters mentioned above, with passengers on platforms (to determine the influence of people on platforms on signal propagation, channel throughput and latency).

In addition to measuring the connection speed, the tests in the three environmental scenarios also included the variation of latency and RSSI according to the distance from the access point. Distance steps of 12 meters from the access point were established and for each step three separate measurements were made to reduce the variation in signal strength due to different interference variations and propagation conditions. Later, the average value was taken into account for the construction of the following diagrams (figure 5.13, fig. 5.14., fig. 5.15.):

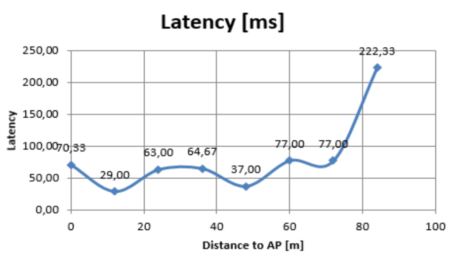

Fig. 5.13. Latency variation as a function of distance in free space

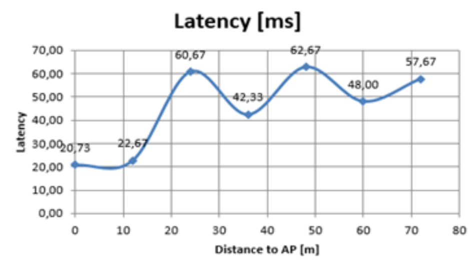

Fig. 5.14. Variation with distance of latency, inside the subway station, without passengers on the platform

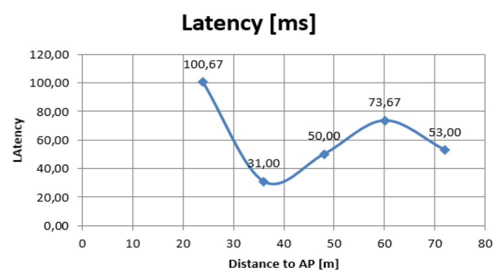

Fig. 5.15. Variation with distance of latency, inside the metro station, with passengers on the platform

The average data speeds recorded under the conditions described above are presented in table 5.1.

Table 5.1. Average data speeds recorded in free space and inside the subway station with passengers on the platform and without passengers on the platform

Terms	**Average download speed [Mbps]**	**Average upload speed [Mbps]**	**Average Latency [ms]**
Free space	26.47	15.20	80.04
Inside the station, no passengers on the platform	30.55	6.60	44.96
Inside the station with many passengers on the platform	9.11	6.02	61.67

The lower average value for the download speed under FOV (free space) conditions can be explained by the presence of numerous access points in the area where the measurement took place, reducing the channel throughput. It can be seen that the environment inside the station favors the data speed to a certain extent by shielding the external field generated by different APs. When passengers carrying active mobile devices enter the station, the data speed deteriorates significantly (Figures 5.16., 5.17., 5.18.).

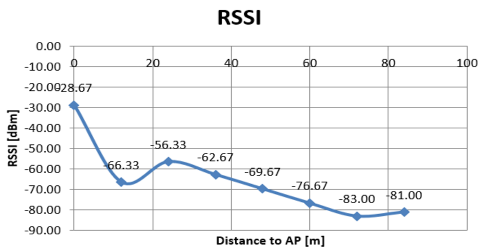

Fig. 5.16. Variation of RSSI with distance, free space

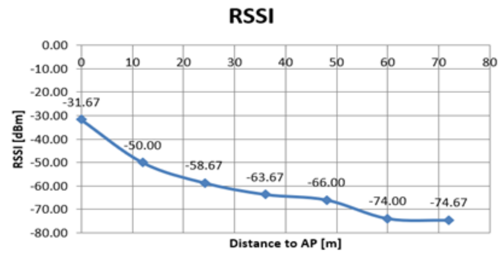

Fig. 5.17. Variation of RSSI with distance, inside the subway station, without passengers on the platform

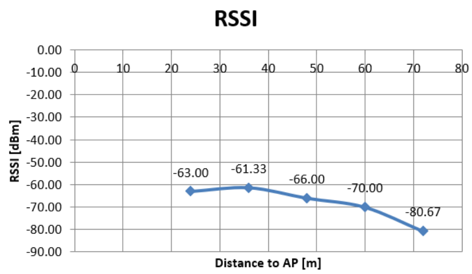

Fig. 5.18. Variation of RSSI with distance, inside the metro station, with passengers on the platform

In figures 5.16., 5.17., 5.18. RSSI levels are shown comparatively, in different situations: same test conditions, one week later (without passengers on platforms, with passengers on platform). It was found that the most suitable distance between APs should be around 35 meters with a tolerance of ± 5 meters for a good reception level, as presented in the first part of the experimental tests. To more accurately assess the influence that platform passengers have on the propagation conditions, the next set of measurements was carried out at a peak hour in the same metro station. The results of this set of field measurements are presented in the following diagrams (figures 5.19., 5.20., 5.21., 5.22., 5.23.).

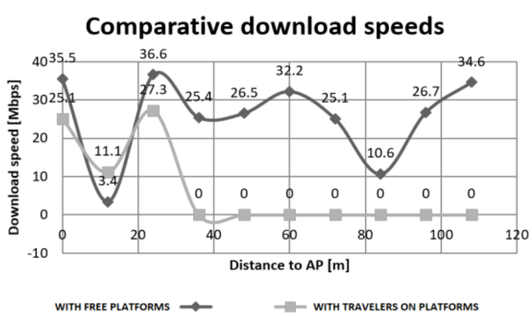

Fig. 5.19. The influence of the presence of passengers on the platform on the unloading speed

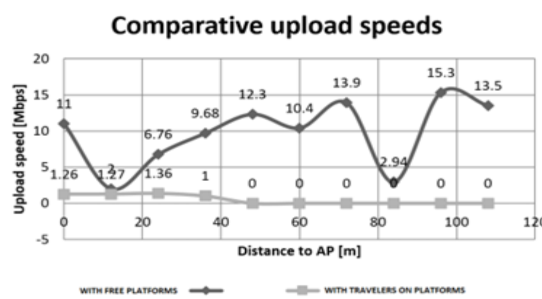

Fig. 5.20. Data upload speed variation across conditions normal and congested

As seen in figure 5.19, the download speed is affected when the platforms are full of people (square dot curve), and after about 40 meters from the access points, the connection was practically lost. At 15 meters from AP the signal drop in both situations was caused by the arrival of a subway in the station. In figure 5.20. the variation of loading speed under normal and congested conditions (with many passengers on the platforms) is shown. One can see that the download speed decreases dramatically when there are many people on the platforms (dotted square line on the diagram), compared to the usual situations with a variable number of people in the station. As in the previous case, the two low peaks were recorded when trains arrived in the station during peak hours with many passengers.

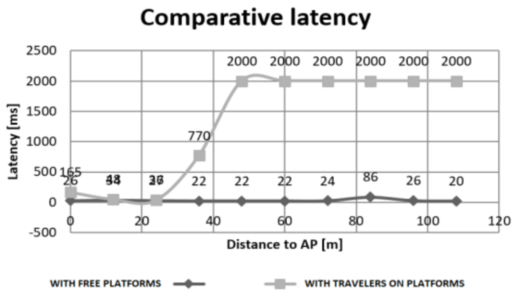

Fig. 5.21. Influence of platform passenger presence on data transmission latency

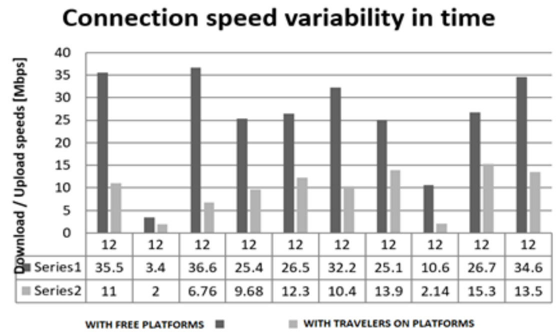

Fig. 5.22. Comparative measurements of the speed of stationary, remote position connection access point constant

Figure 5.21. shows the latency variation in two different cases - dotted line - the evolution under normal stationary conditions, with a variable number of people on the platforms, square dotted line - the evolution in the case of crowded platforms. Latency was found to suffer the most as the number of people sitting on the platform varied. The gray colored bars (figure 5.22.) indicate the situation with many passengers on the platforms - the connection speed drops significantly.

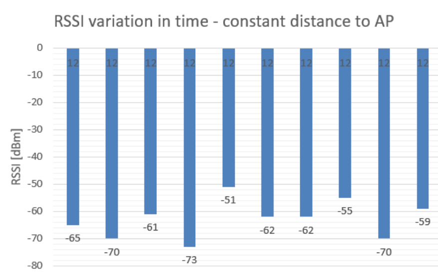

Fig. 5.23. Comparisons of RSSI – stationary position, fixed distance from the access point

5.2.1. Conclusions on Part II of the field tests [156]

Wireless technologies are a relatively young and promising technique for anonymous data collection with the advantage of simple equipment [157], [158], [159]. Access points capable of collecting information such as MAC addresses, timestamps and RSSI levels are sufficient to collect significant amounts of information. A more difficult part is filtering and extracting data when enough information has been collected in a dedicated database. For the case study carried out under the given conditions, in Bucharest, it turned out that, for the moment, a relatively small percentage of people carry detectable Wi-Fi or BT devices: around 4.7%.

5.2.2. CONCLUSIONS FROM FIELD TESTS

5.2.3. Travel Request Data Collection (CDCC) system architecture design

Considering the experimental results from the two parts of the tests, it can be concluded that the architecture of a travel data collection system using an anonymous, wireless data collection solution should consist of (but not limited to) (figure 5.24.): a network of wireless APs, used as sensors for Wi-Fi devices, a local server for collecting, storing and processing local data, a workstation (not mandatory), interface to the Internet through a VPN (Virtual Private Network) and the ability to connect to a Data Center and remotely access the local system.

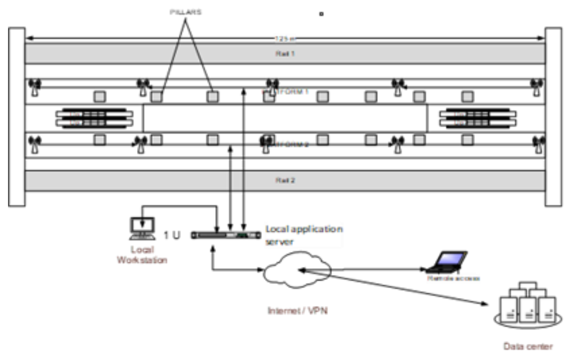

Fig.5.24. The proposed architecture for the CDCC system

The purpose of these tests was to study, under real operating conditions, the propagation behavior of radio signals in a typical environment of a subway station, with moving passengers. It has been observed that the geometry of the medium considerably affects the way radio waves propagate.

The proposed solution is considered simple and efficient in terms of hardware required for the infrastructure, thus significantly reducing the cabling, power supply and maintenance of the sensor network. Access points installed in selected locations can determine the number of detectable Wi-Fi and / or BT devices present in the station.

The results of these tests can provide sufficient information regarding the usefulness and efficiency of the proposed methodology for determining transport demand in congested urban areas.

5.4. System for anonymous collection of position and mobility information in public passenger transport

This solution embodied in Patent No. 134415 / 28.08.2020 is based on a method and a system for the anonymous collection of information related to position and mobility in public passenger transport, road traffic congestion, through Bluetooth and Intelligence Artificial, to improve public transport management systems by supplementing the information they need.

The experimental research considered the collection of information on the estimated number of passengers carried, the estimated number of passengers waiting in public transport stations, the position of the public transport on the route and information on the density / flow of private vehicle traffic on the route on which circulates the means of public transport.

5.4.1. Presentation of the technical solution

The method for the anonymous collection of information related to position and mobility in public passenger transport, based on Bluetooth and Artificial Intelligence, developed in the experimental research is characterized by the fact that it consists of a set of three Bluetooth (BT) sensors: S1, S2, S3 that are located in a means of public transport. They are electrically powered from the vehicle's installation and can communicate by cable with On-Board Unit (UB) type computing equipment also on board the vehicle. The sensors are able to detect via radio waves paired BT devices (BT headphones, smart-watches, fitness bracelets, notebooks, tablets, etc.) and mobile phones in discovery mode or other devices in discovery mode (smart TV, desktop or notebook computers, etc.), acquire information about the device's MAC address, time stamp, radio signal level and transmit this information to the UB on-board unit, where their further processing takes place.

5.4.2. Description of experimental research [177]

Initial experimental research was aimed at determining the possibilities of gathering information about passenger flows and means of transport by anonymous methods, in this case via Bluetooth and/or Wi-Fi technologies. In this sense, several experiments were carried out in places common to passenger and vehicle traffic, such as: subway stations and tunnels, stations of the surface public transport system, along the routes of some means of public transport. As part of the experimental research, several stages were followed for the field measurements as follows:

- The first stage - took place in public passenger transport stations (Apaca route, Iuliu Maniu Ave., direction of travel to Lujerului, nearby transport lines 61, 62, 336, etc.).The measurement time for this measurement was one hour, working day, peak hour. The number of MAC addresses registered by the application used (BLE SCANNER) was noted.

In the table below (table 5.2.) are noted the means of transport registered in the time interval, the time of arrival / departure, as well as the number of vehicles, but also the number of passengers from the station.

Table 5.2. Measurements taken in the public transport station

No. crt.	Name of means of transport	Arrival time	Departure time	No. vehicles - green traffic light	No. travel station/means of transport
1	136	16:54:04	16:54:22	54	30
2	336	16:54:37	16:54:52	30	25
3	336	16:56:48	16:57:08	42	40
4	336	17:01:02	17:01:28	56	45
5	336	17:03:40	17:04:04	38	20
6	61	17:06:20	17:06:42	39	20
7	62	17:06:23	17:06:42	50	25
8	336	17:10:58	17:11:13	49	40
9	61	17:18:26	17:18:38	34	26
10	336	17:18:40	17:18:55	64	20
11	62	17:19:05	17:19:35	43	18
12	136	17:20:06	17:20:20	36	25
13	61	17:21:31	17:21:48	46	15
14	136	17:23:19	17:23:46	46	4
15	62	17:25:22	17:25:40	28	20
16	336	17:25:27	17:25:52	62	15
17	62	17:30:40	17:31:11	41	10
18	336	17:35:53	17:36:17	45	20
19	136	17:38:06	17:38:22	40	40
20	336	17:40:33	17:40:55	51	20
21	336	17:43:18	17:43:37	46	45
22	61	17:43:21	17:43:47	34	25
23	62	17:50:23	17:50:37	37	24
24	62	17:50:25	17:51:05	40	10
25	336	17:52:41	17:53:23	35	10
26	136	17:54:57	17:55:22	32	25
27	336	17:55:03	17:55:28	28	25

- The second stage - the BLUE SCAN application was used in a moving public transport, and the MAC addresses discovered along the route were recorded, from one end to the other on a selected road section (Apaca – Lujerului as well as Lujerului – Apaca). One table (table 5.3.) contains the specific times when the vehicle stopped at its station for the passengers to get on / get off. The number of passengers from the means of transport at each station, upon departure from the station, was estimated. To carry out this measurement, different means of transport were used.

Table 5.3. Measurements carried out in public transport

Data	02.04.2019
Ora	16:57
Nume Participanti la masuratori	Bran Catalina Alexandra Stîngă Anne Marie Chiva Ionut Cosmin
Traseu	Apaca – Lujerului – Dus -Întors

Numar Statie	Nume Statie(DUS)	Ora sosire in statie	Ora plecare din statie	Numar calatori	Nume mijl transp DUS
1	Bl-Vasile Milea	16:59:01	16:59:10	38	61
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 1 si 2
2	UPB	17:00:35	17:00:53	44	1 min și 43 sec
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 2 si 3
3	Liceul Tudor Vladimirescu	17:01:06	17:01:30	32	37 secunde
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 3 si 4
4	Lujerului	17:03:16	17:03:45	27	2 min și 24 secunde
Numar Statie	Nume Statie (Intors)	Ora sosire in statie	Ora plecare din statie	Numar calatori	Nume mijl transp INTORS
4	Lujerului	17:11:17	17:11:42	40	336
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 4 si 3
3	Liceul Tudor Vladimirescu	17:13:22	17:13:44	37	2 min și 2 secunde
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 3 si 2
2	UPB	17:14:50	17:15:10	32	1min și 26 secunde
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 2 si 1
1	Bl-Vasile Milea	17:17:58	17:18:28	23	3 min și 38 secunde

Măsurătoare 2

Numar Statie	Nume Statie(DUS)	Ora sosire in statie	Ora plecare din statie	Numar calatori	Nume mijl transp DUS
1	Bl-Vasile Milea	17:23:40	17:24:00	32	61
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 1 si 2
2	UPB	17:24:54	17:25:10	33	1 min și 10 sec
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 2 si 3
3	Liceul Tudor Vladimirescu	17:26:11	17:26:31	26	1 min și 21 sec
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 3 si 4
4	Lujerului	17:30:15	17:30:41	32	4 min și 10 secunde
Numar Statie	Nume Statie (Intors)	Ora sosire in statie	Ora plecare din statie	Numar calatori	Nume mijl transp INTORS

4	Lujerului	17:41:20	17:41:28	33	62
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 4 si 3
3	Liceul Tudor Vladimirescu	17:42:53	17:43:14	36	1 min și 46 secunde
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 3 si 2
2	UPB	17:44:16	17:44:33	27	1min și 19 secunde
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 2 si 1
1	Bl-Vasile Milea	17:46:20	17:46:40	18	2 min și 07 secunde

Măsurătoare 3

Numar Statie	Nume Statie(DUS)	Ora sosire in statie	Ora plecare din statie	Numar calatori	Nume mijl transp DUS
1	Bl-Vasile Milea	17:50:31	17:50:48	24	136
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 1 si 2
2	UPB	17:51:49	17:52:00	23	1 min și 12 sec
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 2 si 3
3	Liceul Tudor Vladimirescu	17:53:06	17:53:24	20	1 min și 24 sec

Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 3 si 4
4	Lujerului	17:58:01	17:58:18	17	4 min și 54 secunde
Numar Statie	Nume Statie (Intors)	Ora sosire in statie	Ora plecare din statie	Numar calatori	Nume mijl transp INTORS
4	Lujerului	18:04:15	18:04:27	28	62
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 4 si 3
3	Liceul Tudor Vladimirescu	18:05:41	18:05:53	23	1 min și 26 secunde
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 3 si 2
2	UPB	18:06:52	18:07:05	21	1min și 12 secunde
Numar Statie	Nume Statie	Ora sosire in statie	Ora plecare din statie	Numar calatori	Timpul intre statia 2 si 1
1	Bl-Vasile Milea	18:08:42	18:09:02	9	1 min și 57 secunde

Next, in order to be able to filter the previously detected devices, on the same road section, under the same conditions, during the movement of the public transport, using the BLE Analyzer application, the RSSI levels discovered on the route were recorded (figure 5.30Bluetooth headphones were used to be able to establish a detection interval, the data were collected by two people, different means of transport were used (bus, tram, trolleybus). The headset was connected to the phone, it was placed next to the device with the BLE app until the RSSI level (-35/-45) was detected, then the data was collected after the headset was moved to the public transport and at the opposite end of the public transport from the device with the BLE app.

Fig. 5.30. RSSI level of bluetooth headphones at different distances

5.4.3. Interpretation of results [177]

For the first stage, a total of 411 devices / MAC addresses were detected during the one hour spent at the Apaca bus station (going towards Lujerului). The application (BLUESCAN) was opened approximately 2 minutes before the first public transport arrived at the station. It collected data continuously for an hour, after which it was emailed in .csv format directly from the app.

For the appropriate filtering of the collected data, the time interval in which a bus / trolleybus arrived at the station was taken into account, as well as how many people were both in the station and in the means of public transport (figure 5.31.). Vehicles traveling in the same direction as the bus/trolleybus were also counted, as they too could have integrated bluetooth, thus affecting the collected data. Therefore, from the total of 411 devices / MAC addresses, only 139 addresses remained that could be interpreted as trips from the station and from the public transport (figure 5.32.).

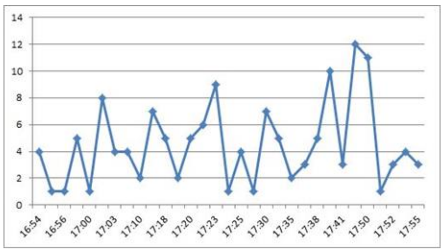

Fig. 5.31. Devices filtered by arrival times of public transport

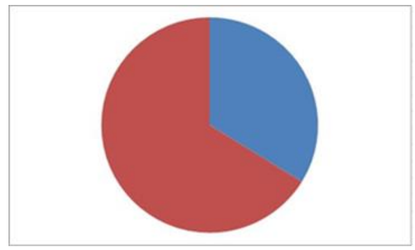

Fig. 5.32. Representation of filtered devices against the total number (33.81% - blue)

For the second stage, measurements were carried out by several teams under the same conditions, at the same times (approximately), with the same application, on the road section Apaca – Lujerului, as well as in the opposite direction, Lujerului – Apaca, accumulating a total of 7 sets of measurements, with a total of 977 devices / MAC addresses detected. The application (BLUESCAN) was used in the following way: every time you got on the bus / trolleybus the application was turned on and left to record until you got off the public transport, after which the data was saved and sent by e-mail in the format .csv, then the application will be turned off and reset to be able to separate the data more easily on the directions of travel.

After performing these measurements, in order to establish a detection interval, another measurement was performed under the same conditions, with Bluetooth headphones. With all this data, the detected addresses were filtered and a different percentage of detected users was obtained depending on the chosen threshold (maximum of -85 dB) (figure 5.33.). After this filtering, the separation of the measurements was followed in order to be able to more easily detect the fixed addresses that appeared in each of them (figure 5.34.).

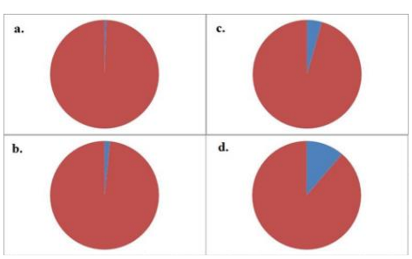

Fig. 5.33. Devices detected according to the chosen threshold a. -70 dB (0.51%) b. -75 dB (1.64%) c. -80 dB (4.40%) d. -85 dB (11.26%)

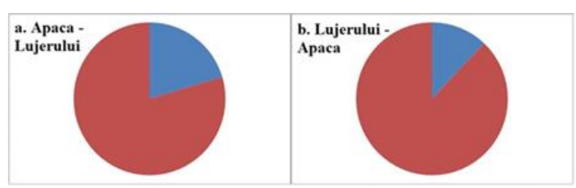

Fig. 5.34. The percentage of fixed addresses in the total (blue) a. 20.36% b. 12.06%

The novel contributions of this experimental research are the following:

- An integrated solution for the anonymous collection of position and mobility data in public passenger transport has been developed. The solution is based on the reception of discoverable Bluetooth devices and performs data analysis with the help of Artificial Intelligence algorithms.
- The zoning operation was performed by combining the Delaunay triangulation with the Voronoi diagram.
- A new constrained Delaunay triangulation algorithm was used, which allows localizations with an error margin of 0.3 m.
- The k-means algorithm was used to cluster the nodes and determine the location vectors based on the clustering method. An ID has been associated with each MAC address.
- The combination of grouping vectors with statistical analysis elements was achieved.
- Representation of data on 2D location maps was carried out.
- The possibility of monitoring the traceability (mobility) of detected nodes was highlighted, with benefits in public transport information systems.
- The proposed solution does not require the support of mobile cellular communication networks to perform the functions and has a very low consumption of electricity.

5.5. System and method for detecting active unmanned aerial vehicles (drones) by analyzing captured sound and image with deep learning algorithms [186]

This scientific research has as its main objective the improvement of the detection systems of unmanned aerial vehicles (human operator) based on their acoustic fingerprints, so as to finally allow their classification according to their constructive models. Unmanned aerial vehicle acoustic signature detection is a difficult task because specific acoustic signals are masked by noises in the detection environment (wind, rain, waves, sound propagation in open field / urban areas). Unlike naturally occurring sounds, unmanned aerial vehicles have distinct sound characteristics. Taking advantage of this aspect, research focuses on building an audio detection, recognition and classification system for the simultaneous detection of multiple unmanned aerial vehicles in the scene of interest.

This method of detecting unmanned aerial vehicles introduces as a main novelty the use of neural networks to train the component modules of the computing architecture

The advantages of this unmanned aerial vehicle detection method are as follows:

- The use of a hardware and software system for the automatic recognition of unmanned aerial vehicles by using specific acoustic components, in order to protect the Critical Infrastructure demarcation areas, according to figure 5.35.

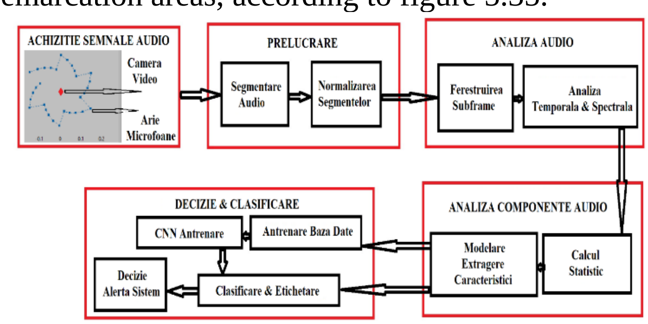

Fig. 5.35. Acoustic system architecture for unmanned aerial vehicle detection.

- Using an array of microphones with a built-in video camera.

- Obtaining a UAV recognition method that works on as large a model base as possible, can be applied independently of the UAV model, is robust to noise, and at the same time provides the best possible response correctly, in the shortest possible time.
- The obtained solution performs a complex spectrum analysis by using the Cohen class spectrogram.
- The solution allows the integration of the acoustic system for the recognition of unmanned aerial vehicles with the video images detected by the camera embedded in the microphone area.
- The solution introduces a new concept of concurrent neural networks for the detection of acoustic signals specific to unmanned aerial vehicles.
- The proposed solution has minimal impact on the environment.
- The proposed solution requires a minimum level of maintenance.

This scientific research implements the notion of "competition" at the level of a collection of neural networks and determines the importance of the inputs that influence the performances in acoustic fingerprint recognition using neural networks. The scientific research uses the Concurrent Neural Networks (CNN) model that combines supervised and unsupervised learning examples to provide an optimal solution for the detection of acoustic fingerprints specific to unmanned aerial vehicles. The experimental results demonstrated that the recognition accuracy is high in the situation where the model proposed in this scientific research is used, compared to the cases where the competition is not used.

The recognition scheme consists of a collection of modules trained on one subproblem each and a module that chooses the best answer. The following figures (figures 5.41 and 5.42) show the training and recognition algorithms that implement these two techniques for time-delayed neural networks, multilayer perceptrons and self-organizing maps.

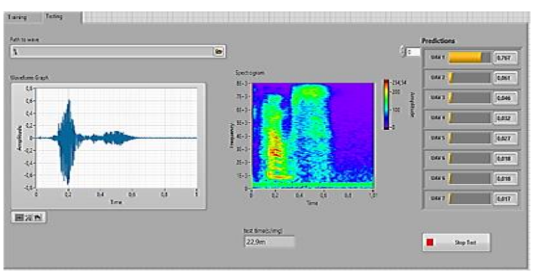

Fig. 5.41. Application interface for detecting and classification of unmanned aerial vehicles: CNN app interface

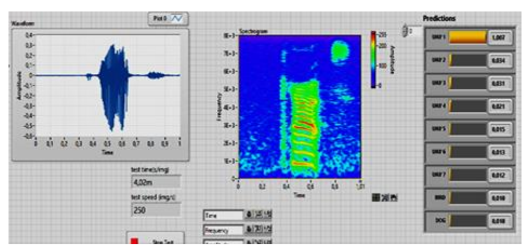

Fig. 5.42. Application interface for detection and classification of unmanned aerial vehicles: application interface for recognition and classification

The model proposed in this scientific research, Concurrent Neural Networks (CNN), introduces a new neural recognition technique based on the idea of competition between several modular neural networks working in parallel. Thus, the model proposed in scientific research represents a collection of neural networks working in parallel, the recognition and classification decision being established according to the "winner takes all" rule. Each component neural network is trained individually with its own set of data.

In figure 5.43. an example of a practical implementation of the unmanned aerial vehicle detection system is presented.

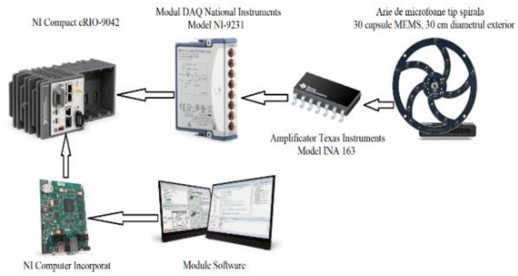

Fig. 5.43. Hardware system architecture for unmanned aerial vehicle detection.

The novel contributions of this scientific research refer to:

- An array of microphones arranged in the form of a spiral, with multi-channel adaptive weights, with variable pitch, was used to provide the possibility of detecting the acoustic signal of reduced complexity (reduced acoustic energy);
- A new Concurrent Neural Networks (CNN) classification model was introduced as a collection of small neural networks working in parallel, the classification being performed according to the "winner takes all" rule;
- The system consists of neural networks with different architectures;
- Multilayer perceptron, time-delay neural network and self-organizing map (SOM) modules were used;
- The recognition scheme consisted of a collection of modules trained on each subproblem and a module to select the best answer. Each neural network component of the system was trained separately so that it responds correctly to inputs from a single class;
- The training is supervised and the number of networks used is equal to the number of classes in which the vectors are grouped;
- A complex algorithm was used to integrate information obtained from different sources, acoustic and video, thus increasing the probability of recognition and classification of unmanned aerial vehicles.

CHAPTER 6 – START-UP: DEVELOPMENT OF A SOFTWARE APPLICATION FOR MONITORING PUBLIC PASSENGER TRANSPORT

6.1. General business information (table 6.1)

Table 6.1. General information

General information				
The name of the business idea	S.C. TRANSSOLUTIONS S.R.L.			
Name and surname of the applicant	IONUŢ-COSMIN CHIVA			
Applicant's address	Str. XXXXX, no. XX, ap. XX, Bucharest, sector 6			
County	Bucharest			
Postal code	060754			
Phone number	(+40)72X XXX XXX			
E-mail:	transsolution2023@gmail.com			
The headquarters of the company and the work points	Splaiul Independenţei 291-293, Bucharest 060042, set of office buildings Riverside Tower			
The total value of the investment project related to the implementation period of the business plan (lei - VAT included)	750 000 lei			
Number of jobs to be created following the implementation of the business	4			
Field of activity	**Output**	**Services**	**Trade**	**CAEN code**
Custom software creation activities (customer-oriented software)		X		6201

6.2. Business idea summary

The start-up aims to create a bespoke software application for monitoring public passenger transport, MooovApp.

Thus, the developed product proposes a support platform for real-time predictive decisions, which addresses both road traffic control and passenger information needs. The application will be able to provide forecasts of crowding in public transport and stations based on real-time traffic information, taking into account unpredictable events that may occur. It will then communicate this information to passengers and take into account their response to the information provided. It will also accurately specify the duration of the routes and adjust along the journey. We considered that by providing predictive information to passengers, crowding in public transport can be reduced, a fact that has as its main consequence a better use of their capacity.

The developed application uses real-time predictive models that include both public transit station arrivals, real-time origin-destination predictions, and predictive information to support passenger travel decisions. Through the app downloaded to the phone, passengers receive real-time information on, for example, bus arrivals (which changes the way waiting times are traditionally estimated), updates on incidents and can give feedback to road users about all these events.

6.3.Result

6.3.1. Quantifiable results

The projection for the first year of the company's activity, but also for the next 3 years, is illustrated in the table below (table 6.2.). The target indicators for the next 3 years are based on an annual demand growth rate of approximately 15%.

Table 6.2. Projection for the company's activity (4 years)

Target indicators	UM	2023	2024	2025	2026
Fiscal value	Lei, without VAT	661 500	980 000	1 176 000	1 347 500
Advantage	Lei, without VAT	-139 628	58 406	233 627	300 150
Number of employees	Number of people	4	4	4	4

6.3.2. PrintScreen from the application design (fig.6.2. and fig.6.3.)

The simulation of the MooovApp application was carried out with the help of the SIGMA application (Graphic Interactive System for Management in Administration).

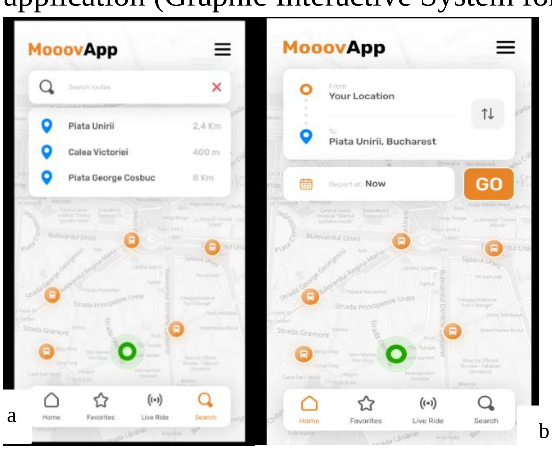

Figure 6.2. a) The opening image of the application,
b) The existing means of transport around the passenger's location

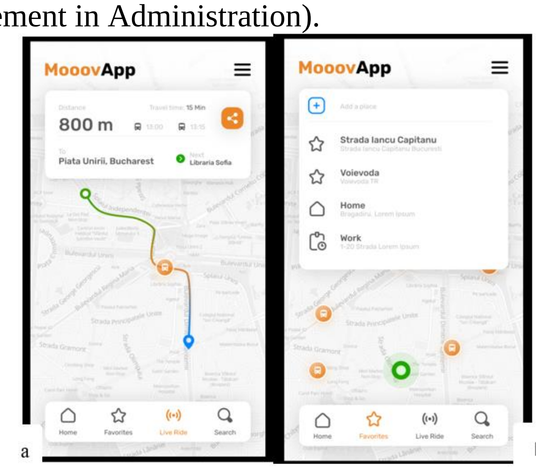

Figure 6.3. a) Route in real time, b) Previous, previous saved routes

6.3.3. Pricing policy

The following table shows the company's revenue and expenses forecasts for the next three years.

Table 6.18. Revenue and expenditure forecasts for the next 3 years

No. crt.	Category	Year 0 (according to the Budget)	Year 1	Year 2	Year 3
1	Total income (lei excl VAT)	**661 500**	**980 000**	**1 176 000**	**1 347 500**
2	Total expenses (lei excl VAT)	**801 128**	**910 468**	**897 818**	**990 178**
3	Gross profit/loss	**- 139 628**	**69 532**	**278 182**	**357 322**
4	Corporate tax (16%)	**-**	**11 125, 12**	**44 509, 12**	**57 171,52**
5	Net profit/net loss	**- 139 628**	**58 406, 88**	**233 627, 88**	**300 150,48**

For the 1st year, we considered that the company will sell a number of 40 software applications with a price of approximately 5,000 euros/pc, without VAT (total 980,000 lei without VAT). For the calculation of personnel expenses, we considered that all employees will be paid for 12 months, with the salaries shown in table 8 (total 740,640 lei without VAT). We also took into account the depreciation of the equipment. I have not added the expenses with notary and financial fees. The rest of the expenses remain unchanged.

For the 2nd year, we considered that the company will sell a number of 48 software applications with a price of approximately 5,000 euros/pc, without VAT (total 1,260,000 lei without VAT).

For the calculation of personnel expenses, we considered that all employees will be paid for 12 months, with the salaries shown in table 8 (total 740,640 lei without VAT).

We did not take into account the depreciation of the equipment. I have added expenses for staff travel and trips to conferences, fairs and participation fees (total 20,000 lei without VAT). We considered the advertising and marketing expenses to be in the amount of 50,000 lei, a smaller amount compared to previous years. We have increased office operating costs (consumables) to a value of 5,000 lei without VAT.

For the 3rd year, we considered that the company will sell a number of 55 software applications with a price of approximately 5,000 euros/pc, without VAT (total 1,347,500 lei without VAT).

For the calculation of personnel expenses, we considered that the salaries of employees will increase, a total of 810,000 lei without VAT.

I have added expenses for staff travel and trips to conferences, fairs and participation fees (total 40,000 lei without VAT). I considered the advertising and marketing expenses to be in the amount of 50,000 lei. We have increased office operating costs (consumables) to a value of 8,000 lei without VAT.

CHAPTER 7 - GENERAL CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

7.1. General conclusions

The main conclusions that emerge from the experimental research carried out within this doctoral thesis are the following:

- The quality index, the extent to which the road transport service satisfies the level of expectation of the user / traveler in relation to a certain trip, is based on a series of factors that together contribute to the increase in the quality of road transport;

- The purpose of a clear legislative framework regarding the use of unmanned aerial vehicles aims both to ensure and support their use in various fields, as well as to guarantee people's life and health, property and private life, state security and, more than that, flight safety and aeronautical security;
- A number of propagation attenuation models for Wi-Fi signals have been identified in the literature, and a number of researches have been presented that describe different methods for locating people as accurately as possible;
- Also, in the specialized literature, research was identified for the monitoring of unmanned aerial vehicles based on the acoustic footprint;
- The advantages of using artificial intelligence in intelligent transport systems were presented;
- Based on specialized literature, 5 innovative solutions were developed for road and air traffic management;
- Field tests were carried out, the main purpose of which was to study in real operating conditions the behavior of radio signal propagation in a typical environment of a subway station, with passengers traveling;
- An original solution was developed, materialized through an invention patent no. 134415 / 28.08.2020 "System for anonymous collection of position and mobility information in public passenger transport";
- The solution involves a simple, anonymous method of collecting (without the possibility of associating people with the detected devices) data on the flows of passengers transported or waiting in passenger stations, information related to the position of public transport vehicles on the route, as well as density of private vehicle traffic on the public transport route;
- An original solution was developed, materialized through an patent application (C.B.I), "System and method for detecting active unmanned aerial vehicles (drones), by analyzing the captured sound and image with deep learning algorithms ";
- The developed solution involves the detection, identification and classification of unmanned aerial vehicles according to their acoustic signature, by using a system of concurrent neural networks;
- A software application for monitoring public passenger transport, MooovApp, was developed. From the point of view of economic opportunity, this software product can form the basis of a successful business plan.

7.2. The original contributions resulting from the experimental research are represented by the Patent and the application for the patent, by the tests carried out in the field, but also by the 5 solutions developed based on the specialized literature:

- The first part of the experimental field tests involved the development of a solution for collecting information about travelers in a subway station and in trains based on the anonymous detection of the number of Wi-Fi (or Bluetooth) devices carried by travelers.
- The second part of the experimental field tests was carried out in three environmental scenarios (indoor environment, inside the metro station, without passengers on the platform, inside the metro station, with passengers on the platform) and aimed to evaluate the conditions indoor signal propagation, in particular for Wi-Fi channel 1 (2.4 GHz band), to support an anonymous passenger flow determination solution in similar environments. Calibration tests were carried out in the open field, the collected data served as a reference for the measurements carried out in the indoor environment.

- An innovative solution was developed, realized through an patent no. 134415 / 28.08.2020 "System for anonymous collection of position and mobility information in public passenger transport" which is based on a method and system for the anonymous collection of information related to position and mobility in public passenger transport, at congestion road traffic, through Bluetooth and Artificial Intelligence, to improve public transport management systems by supplementing the information they need.
- An innovative solution was developed through an patent application (C.B.I), "System and method for detecting active unmanned aerial vehicles (drones), by analyzing the captured sound and image with deep learning algorithms" which has the main objective of improving the detection systems of unmanned aerial vehicles (human operator) based on their acoustic fingerprints, so as to allow their classification according to their constructive models.
- The technical problem solved in this research involves the design of a method for the detection, identification and classification of unmanned aerial vehicles according to their acoustic signature, by using a system of concurrent neural networks.
- A business plan was developed that highlighted the economic-financial opportunity of developing a software application for monitoring public passenger transport.
- As part of the business plan, a software solution for passenger transport management in Bucharest, called MooovApp, was developed.

7.3. Future research directions

Future research will consider several aspects:

- Carrying out a more in-depth preliminary study to determine the exact proportion of travelers with Wi-Fi (or Bluetooth) devices in a total mass of people, to see the relevance of detected people compared to the total flow of passengers;
- The establishment of a large database, dedicated to road traffic management so that it is possible to improve the solutions developed in the doctoral thesis;
- BT technology will be used in combination with Wi-Fi technology for passenger flow detection and indoor orientation;
- The development of other innovative solutions for monitoring road traffic will be attempted, solutions that could take into consideration the identification of the possibility of replacing, to a large extent, transport by personal vehicles with public transport, provided that it is made attractive, regular and responsive to transport demand;
- Future research will also consider the development of algorithms based on fuzzy logic for estimating the trajectory of an unmanned aerial vehicle in airspace, with the aim of increasing personal safety and security.

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