Implementation of UAV for environment monitoring of a Smart City with an airspace regulation by AIXM-format data streaming

Vladyslav Alieksieiev [1,2], Bohdan Markovych [1,3]

[1] Lviv Polytechnic National University, Lviv, Ukraine

[2] vladyslav.i.alieksieiev@lpnu.ua, https://orcid.org/0000-0003-0712-0120
[3] bohdan.m.markovych@lpnu.ua, https://orcid.org/0000-0002-8813-9108

Abstract: *One of the most expected and the most desired implementation of modern technologies is the concept of a Smart City. Meanwhile there are many buzz-words known to describe the ability of implementation of many approaches to provide control for Smart City. Many of such technologies had become known for Industry 4.0 concept, including 5G mobile Internet and autonomous aerial vehicles (so called drones). Nevertheless, there is an open question of how to provide and support limits where and when UAV (unmanned aerial vehicle) should be able or not to fly over the city. Naturally, the self-driven drones equipped with a batch of sensors and able to avoid some obstacles would not be enough for everyday use within Smart City. Current paper is focused on discussion of possible solution to provide UAV with up-to-date data on restrictions, that may be required in a modern city.*

Keywords: SMART CITY, ENVIRONMENT MONITORING, AIRSPACE REGULATION, INDUSTRY 4.0, UAV, AIXM

1. Introduction

A modern understanding of a 'Smart City' had evolved actively during recent years and implies implementation of most contemporary integrated information and communication technologies to produce, develop, improve and yield common wealth to a local community. Coming initially (according to [1]) from idea of sustainability to cities via providing its development with leading technological solutions, the concept had become later a natural part within a wider concept of a Fourth Industrial Revolution [2] or Industry 4.0.

Nowadays, it is actually impossible to see a strict border between modern city and modern manufacturing in the same way like it was possible even in previous 20th century. The 'Smart City' should be now considered as a big quasi-industrial area which produces, supplies, supports and consumes huge amounts of products and services. The problem of convenient lifestyle had gone outbound of simple concept of dwelling, and it becomes more and more complex in each next decade. Technologies, and ICT in particular, permeate deeper and deeper into everyday life of each citizen and surround the communities in a new transparent manner, giving a new sense of collaborative existence for the whole city. One of a key modern aspects and a technology that changes the face of any our city into the 'Smart City' is named 'Cyber-physical System' (CPS). CPSs bring smart automation into our life. A significant role in integration of CPSs into Smart City will take an army of autonomous flying robots (in different sources there were different terms and abbreviations used, like UAV for 'Unmanned Aerial Vehicles', or UFV for 'Unmanned Flying Vehicles', or UAS for 'Unmanned Aerial System'), known also simply as 'drones'. These smart machines should serve people and cities for many known purposes, but in a new way.

There is a number of already known and actively developed smart robots which came to modern cities already. Among such smart solutions there are delivery robots (see Fig. 1) – autonomous wheel robots from Estonian company "Starship Technologies" [3]: "According to the concept, those robots will deliver everything from shopping bags to internet purchases, pizzas and many other things, freeing us from wasting time and energy on such daily chores". Surely, these kind of robots are pioneers in their field and developers know themselves of their main problem [3]: "As the robot will just be delivering the package to the front of the address and not bring it up in an elevator or staircase, it would be pretty strange to order a pizza in a Hong Kong high rise and to then discover that the whole front of the building is full of robots".

The more promising, from perspective of mobility, among autonomous robots are drones, the flying brothers of a street wheel robots. Fortunately, we also have a number of examples of successful implementations in the area already.

Fig. 1 *Delivery robot from Estonian company "Starship Technologies" in urban landscape (image retrieved from [3])*

The concept of air deliveries was actively developed in recent years by Amazon [4, 5]. The first fully autonomous air drone delivery from Amazon Prime Air was announced to be made on December 7, 2016 [4] (see Fig. 2).

Fig. 2 *Delivery drone from Amazon Prime Air (image retrieved from [4])*

And Amazon didn't stop with that, presenting their new fully electric delivery drones in June, 2019 [5] (see Fig. 3). These drones looked different to the previous generation of delivery drones. So, the fleet of delivery drones includes quite different flying machines able to carry different kind of parcels of different sizes and weights.

Fig. 3 *Presentation by Jeff Wilke of fully electric delivery drone from Amazon Prime Air at "re:Mars" conference in Las Vegas (image retrieved from [5], photo by Jordan Stead, Amazon)*

However, UAV and wheel robots for delivery services can be the first ones in the airspace and in the streets of Smart Cities, but not the only ones to serve people with their needs. Let's have look at industrial implementations of UAV, and purposes and services provided with such drones. In December, 2016 Audi had presented their vision for the future of their car manufacturing and one of their innovations was to involve flying drones to transport parts to the particular place for the conveyor [6, 7] (see Fig. 4).

Fig. 4 *Audi smart factories using drones to transport parts (image retrieved from [6])*

A great benefit from flying drones was found for smart agriculture. India has a successful experience in that area: "The aim of the Syngenta-Skylark project was simple: count the number of germinated seedlings and plants across corn farms using Syngenta seeds with an intent to see how to increase productivity" [8]. Another successful drone usage for monitoring in agriculture and implementation of precision agriculture according to [8]: "... company Cyient and a leading fertilizer company in south India are working together on a precision agriculture project to monitor farms using drones in order to monitor and act on crop health. … The idea is to identify areas that are stressed, either due to a nutrient deficiency or affected by weeds or pests, and alert farmers in the form of digital prescriptions." All these implementations revealed a significant impact on quality of agricultural processes not only in way of looking at the situation in a whole and making some decision, but also in a way of supplying exact quantities of chemicals to particular plants and not to make unnecessary influence and chemical pollution for the rest of normal growing plants (see Fig. 5).

Fig. 5 *Drones used for agriculture in India (image retrieved from [8])*

One of the world's biggest steelmakers declared the use of drones to provide more safe industrial manufacturing: "New ways of incorporating drones into the workforce are popping up everywhere, such as for marketing, expedient delivery and information gathering. In heavy industries like steel manufacturing, drones are playing an increasingly important role in workplace safety. When paired with AI, drones have even more possibilities for minimizing workplace hazards." [9] (see Fig. 6). And also more precise, agile and safe monitoring is available: "…steelmaker POSCO is incorporating drones into its smart factory to monitor gas leaks that are hard to detect" [9].

Fig. 6 *Drones used for monitoring at steel manufacturing company POSCO, South Korea (image retrieved from [9])*

Drones are used in factory automation for critical safety issues: "The interconnected and interdependent nature of the bulk power system requires a consistent and systematic application of risk mitigation across the entire grid system to be truly effective" [10] (see Fig. 7).

Fig. 7 *Drones used for monitoring of industrial safety in USA (image retrieved from [10])*

Current drones' areas of application are widely known: "UASs of all types have already been used in a wide variety of applications in practical ways, such as aerial photography, agriculture, commercial delivery, entertainment, exploration, national defense, public safety, surveying, and thermography" [10].

Obviously, growing sets of features and abilities, that drones can provide to different industries, are very promising for development in number of new areas, like Smart City needs. This growth leads also to inevitable question of coordination and regulation of drones' flights. The focus of our current research is the problem of necessity of regulation of UAV flights within modern smart city.

2. Prerequisites and means for solving the problem

Modern city can be much more complex if to compare with above mentioned use cases of industrial implementations of drones. Besides deliveries in an urban area, among the possible uses for UAV in Smart City there various monitoring purposes that not just imply but require all of the following and even more:

- People support and crowds monitoring – similar to personal workers' safety support in steel manufacturing.
- Safety and accident monitoring – same as in steel manufacturing (or any other dangerous manufacturing processes).
- Leaks monitoring – same as in industrial dangerous gases and liquids supply systems.
- Power supply lines and power grids monitoring – exactly the same as in power grids systems.
- Plants growing and monitoring – same as in precision agriculture.
- Animals monitoring – same as in precision agriculture and breeding.

Considering these and many other possible implementations of UAV useful abilities, one can conclude that at least two important aspects would be brought with UAV utilization in Smart City:

1. Changes in citizens' lifestyle.
2. Management for UAV as a whole system.

Example for the first aspect can be found in area of delivery robots and drones. Currently, most citizens are visiting supermarkets, big stores or small shops to buy goods, food etc. The city transport infrastructures are used to provide people with ability to go between their homes and places where they buy anything. Even in case of making orders by phone or in Internet, many delivery services use courier services to deliver purchases to clients and again city transport infrastructure suffer with additional load (due to growing demand). During rush hours these deliveries will also yield the growth of delays. These delays impact not only delivery services but also public transport and personal vehicles. Now, providing citizens with efficient delivery services utilizing UAV, the impact on on-ground infrastructure and the lifestyle will change: citizens will reduce their need to spend time in traffic jams and will gain a little bit more of free time for other activities.

The second aspect comes from creation of new infrastructure (the infrastructure for UAV) and from utilization of new spaces (the airspace) and facilities (take-off and landing, fueling or charging, maintenance and support). Meanwhile, UAV should avoid collisions and excessive airspace congestion (due to inevitable unwanted crashes and noise pollution). Another big problem is an impact on city ecosystem (birds and many other flying species will suffer more and more from human activity). Evidently, all this complexity leads to demand of management and regulation for the whole new system of UAV within Smart City.

Our current suggestion is to develop the idea and approach for industrial implementation of airspace regulation [11] for the Smart Cities and, in particular, for the purpose of environment monitoring. The experience of aviation in data exchange, like AIXM [12], and rather difficult cases of governance in airspaces performed by international organizations, like EuroControl [13], can provide Smart Cities with a good examples of airspace management. In example, if compare UAV, which are self-driven, to aircraft flights we suggest to use VFR and IFR flights as analogues for drones to fly relying on own sensors only or to fly following some given prescriptions. Hence, based on known experience, some problems could be identified and solved initially.

One of the key problems here is the problem of data exchange to provide UAV with up-to-date restrictions. Unlike to aviation, there is no pilot to speak to dispatchers, who can provide flight support from the ground. Also, the AIXM data format is based on XML notation supplemented with GML extension [14], and the source files volume requires huge channel capacity to perform data transmission. While each millisecond in flight is precious, data transmitting time measured in seconds or minutes looks feasible only before take-off and after landing, but not during the flight. As an example, the set of source files describing navigation data and flight conditions for Europe has volume about 1 Gb in original text format (in XML notation) or about 80 Mb in compressed format (zip-packed files). Considering the number of objects and possible limitations in modern city, the description of a single city airspace wouldn't have less volume of data.

3. Solution of the examined problem

As one can calculate easily, deployment of 1 Gb of data arises many problems:

1. Is it worth uploading the full data set for the flight before take-off? This is appropriate for short time flights, but what about a long lasting ones?
2. How can city provide UAV with immediate updates of data during the flight?
3. Would it be efficient to rely on external data storage and allow network access (via 4G/5G wireless network)?

It looks obvious, that single solution cannot provide the required reliability and a combination of approaches should be used.

Let's consider the problem of data volume and an approach to overcome this obstacle. Uploading data into UAV memory (data storage) requires regular upgrade of memory blocks to increase the capacity. On one hand, this is not a big problem, while UAV should have maintenance and support regularly. On the other hand, it reduces the ability of in-flight automatic regulation. For example, when some accident happens and an airspace should be used by emergency services drones only and not by delivery drones, how should the city dynamically provide all the drones with the restriction? This requires an update, which can be made via wireless network (WiFi hot spots or mobile 4G/5G) from a data server.

The opposite case of relying on data transmissions only looks also inappropriate due to possible communication problems via wireless networks etc. So, the UAV will require to upload most current dump of data before take-off and during the flight to check for updates (itself) or being securely forced to update data (via some kind of notifications). Here again the UAV faces the problem of data volume and time losses. Downloading data in a raw XML format will require a time consuming parsing to "understand" data. Also, if to download a complete data set it will produce a rather big time delay to deploy at UAV. But if to download a portion of data, it may also take some time to parse it and to find the right place to deploy it (replace existing data fragment or add new one). Here the good known technique of remote database can help. Our suggestion is to rely in this case on relational databases, which are a good developed tool for operations with data, which can be updated often (unlike to no-SQL databases, which showed good in often data selects but are less useful in situation with often updates).

To solve this problem, we had developed a software to convert plain text of XML based AIXM format into relational database.

Deploying such database on both UAV and data server gives a good opportunity to perform data exchange in more compact format, than the original AIXM format provides. Nevertheless, the database schema follows the detailed structure of AIXM format and allows to keep all the variety, that AIXM brings. Evidently, that utilization of SQL queries makes easier both development of software for UAV and data servers of Smart City.

Using this technique allow to build and develop the structure of urban airspace. Flying drones are able to provide an up-to-date information about current situation in the city and make it possible to perform dynamic regulation of city airspace. Also, an automated invoke of drones' assistance and request for services becomes available. The optimized for relational database AIXM data format allows to set up efficient data exchange and streaming of updates in a quick and easy to use way.

4. Results and discussion

Our experiments were made with navigational data published for aviation purposes by EuroControl and provided by RocketRoute company [15]. The data conversion takes two major steps:

- Parsing XML and preparing SQL statements to create data structure and insert data – took about 114 seconds on approximately 1 Gb of source files (data volume in SQL format reduced to approximately 800 Mb – about 20% in compare to original AIXM notation).
- Executing SQL statements to deploy the database – took about 354 seconds (the volume of database with indexes raised to approximately 1.5 Gb).

The implementation of described ideas and software applications requires further research with city circumstances and particular drone fleet.

5. Conclusion

We offer to implement known industrial standard from aviation to provide Smart City with ability to manage airspace and establish unified control for UAV.

Using the techniques discussed above will allow to establish a reliable urban environment monitoring systems and provide many different applications of UAV to support industrial services within modern cities.

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7. Literature

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