Chapter 17
UAVs and Their Role in Future Cities and Industries

Bruno Nazário Coelho

Abstract Unmanned aerial vehicles (UAVs) have been used in several different fields. Each day, new applications for these devices arise. Also called RPA (remotely piloted aircraft) or popularly known by drones, they are becoming cheaper and more accessible to the whole population. Undoubtedly, the UAVs will play a fundamental role in the everyday life of the smart cities, urban areas, and industries, contributing to the improvement of the quality of life in its most different aspects. These devices can provide information acquisition about the industrial process and its equipment, data of raw materials yard, and also information about remote areas. Companies can benefit from UAVs applications either acting directly in the industrial process or simply with the acquisition of aerial images for specific purposes. In this chapter, some of the main applications of UAVs and their role in smart cities and industries as well as their characteristics and some of the most promising developments are presented. Several examples of applications along the production chain of heavy industries and for the primary sector of the economy are approached.

17.1 Introduction

A new era has dawned with the arrival of new technologies and new ways of seeing the world, which is now much more seen from above due to the popularization of portable and low-cost unmanned aerial vehicles (UAVs), which have been used in the most diverse applications, from transportation to the acquisition of important data and information. When remotely piloted, these equipment are also called RPA (remotely piloted aircraft), being a more commonly used term when facing the industrial and professional areas. These devices are popularly known as drones, with their characteristic buzzing sound, these small flying objects have brought joy for children, fun for young and old people, and astonishment for others. They are

B. N. Coelho (✉)
UFSJ - Federal University of São João del-Rei, Ouro Branco, Brazil
e-mail: brunocoelho@ufsj.edu.br

V. N. Coelho et al. (eds.), *Smart and Digital Cities*, Urban Computing,
https://doi.org/10.1007/978-3-030-12255-3_17

also the source of income for many people nowadays, the research object of many studies, and the solution of industrial problems in various sectors.

Its history is older than many may think [1]. The first UAVs arose in the first decades of the last century, aimed mainly at military applications. Since then, its development has been widely diffused, but only in the last decades have it gone beyond these applications.

The wide spreading of portable electronics in the last two decades has brought a new phase to the history of mankind. Together with internet access, it provided a great ease of access to information and knowledge, previously restricted to the most favored classes. Over time, several sensors have been added to these portable electronic devices—especially to smartphones—in order to facilitate their use and provide new and better experiences of navigation and interactivity for the consumers. Consequently, it encouraged the development and cheapening of the sensors (accelerometers, gyroscopes, magnetometer/digital compass, barometer, etc.), which later enabled the production of UAVs at a very affordable cost to a large part of the population.

These aerial vehicles became rapidly popular, initially by hobbyists of aeromodelling, but soon after, their use was extended by companies specialized in filming and photography. They have finally taken over the stores and can be easily purchased by anyone for the most diverse purposes. Today, these equipment are the source of sustenance for numerous independent professionals and companies that provide services that depend on the skills provided by these aerial vehicles.

In a more general aspect in the cities, the administrators and the population itself have sought to integrate the new technologies with daily activities, promoting a great diversification in their uses and applicabilities. For the UAVs it is not different, every day new studies on the use of these equipment in new situations emerge, which often put their capacities on test and push their limits to the extreme.

The industries follow the same pattern, constantly seeking new technologies in order to get ahead of their competitors, due to the high competitiveness and market demand. Although the use of drones in the industry is not directly related to the industrial internet of things (IIoT) and the Industry 4.0, its use in the industrial environment often appears to be the first step towards the use of innovations. This is probably for the reason that drones attract attention, generating a much stronger visual marketing than if compared with the implementation of cyber-physical systems that characterize IIoT and Industry 4.0.

In this chapter, some of the main applications of UAVs will be presented, as well as their role in smart cities and industries, their characteristics, and the most promising developments related to this technology. Several applications along the production chain will be approached to exemplify its use in heavy industries and in the primary sector of the economy.

17.2 Smart Cities

The term smart city has been increasingly used in the last two decades and the number of related works has also expanded exponentially. A large part of the researches emphasizes mainly the technological aspects of the smart city systems, but other studies highlight the social aspects in question. An interesting and detailed bibliometric analysis on smart cities can be seen in [2], where the authors address their growth in the most diverse aspects, their divergences, and subdivisions.

Numerous applications for the use of UAVs in urban centers have been evaluated, and large companies have invested huge amounts of money in research related to incorporating these aerial vehicles to perform routine tasks. In smart cities, UAVs can contribute to achieve greater efficiency in different sectors, working in a distributed way and with task exchange between multiple vehicles, adding technological value while also directly influencing social aspects.

Based on a published work which presents six characteristics of a smart city [3], it is possible to make a correlation between the application of UAVs in smart cities according to these characteristics:

- Smart economy,
- Smart people,
- Smart governance,
- Smart mobility,
- Smart environment, and
- Smart living.

These characteristics are, in fact, six sectors of a society, which can be adopted as umbrella terms that represent several other areas. Correlating the possibilities of UAVs applications with these characteristics of a smart city presented by the authors, it is observed that this technology can certainly influence and play an active role in all of them. The use of UAVs can contribute to the smart economy by promoting competitiveness in the market and providing agility and flexibility in collecting and delivering small products over longer distances and in a short term. Consequently, it stimulates the economy and enables small local businesses to reach a larger public and a larger area of coverage. Increasingly, large retail companies are investing huge amounts of money in the development of new transportation possibilities for small consumer goods, streamlining the purchases and deliveries of their products. Regarding the smart people, the UAVs will help in the acquisition of data and information that will contribute to solve social problems, influencing social and human capital. In relation to the smart mobility aspect, they will support traffic services and local accessibility, as well as be applied in mapping and analyzing the coverage area and signal quality of antennas, expanding the availability of information and communication technology (ICT) infrastructure. In the scope of smart governance, the UAVs will contribute with data and information of scenarios for decision making. Concerning the smart living feature, they may be used in several applications to improve health conditions, as well as facilitating humans daily life. For instance, acting in the transportation of equipment for emergencies, in accidents in remote places, in search operations, in disaster aid, etc. They will provide rapid delivery of medicines to hard-to-reach places. In addition, they will contribute to individual safety with air monitoring, and patrols, providing greater flexibility and coverage area for security officers. The smart living concept also involves houses and buildings. In this sense, it is noteworthy the applications of UAVs for autonomous cleaning of building glass facades and house painting. Finally, with regard to the smart environment, they will act directly in the monitoring and accomplishment of tasks in nature, in parks, in isolated and remote areas, and natural resources. They will provide assistance and rapid relief in case of environmental disasters and search and rescue operations. They will also contribute with the acquisition of information to control pollution, forest fires, and environmental protection.

These are just a few examples of how drones can be applied in the most diverse aspects of a smart city. In some cases, they will act more directly than in others, but in any case they will contribute to a wide range of factors. There is still much to be discussed in relation to norms and legislation for the use of UAVs within cities. Each country has been working on its own legislation, according to its interests, but the main aspect that can limit their use are safety issues.

Drones applications currently occur in an isolated way, with practically no integration and information sharing between the systems. The trend is increasingly for multi-agent systems, where multiple UAVs will work in an integrated and joint manner, being able to be reallocated to several applications in numerous systems in a dynamic way. The complete integration of the equipment and information of several areas will be obtained only over time and after the consolidation of the uses in each of them.

17.3 Smart Industries

The industries are increasingly opening their gates for the application of new technologies that can bring benefits to the productive processes, which currently includes the use of UAVs within the industrial area. Many of them have invested in research for the development of the most diverse applications that can bring more safety and reduce production costs. These applications required more robust and more reliable drones, with higher payloads that meet the requirements for safe flights within the industrial environment. These devices can provide the acquisition of information about the process equipment, data of raw materials yard, and information from remote areas and hard-to-reach locations.

Most companies can benefit from UAV applications, both directly, acting in their process, and indirectly, with simple acquisition of aerial images for specific purposes. In this article, the main focus is on applications for primary and heavy industries, more specifically for applications in the mining production chain and throughout the production process in the steel industry.

17.3.1 Mining Industry

Currently, there are several projects and ongoing research involving the use of UAVs in the mining industry. Most current applications are related to the acquisition of aerial imagery, but new ideas for different applications have been investigated.

Most of the applications are focused on open-pit mining, but researches on mapping underground areas and underground mining can also be found [4]. In underground situations, the major difficulty is the limitations of antennas and GPS signal range, and in simultaneous localization and mapping (SLAM) during autonomous flights.

17.3.1.1 Open-Pit Mining

In the open-pit mining, there is a wide range of possibilities for the use of UAVs. Several researches have been developed in search of improvement in information acquisition and safety aspects.

Currently, the main application of UAVs in open-pit mining is in the mapping of the mine and the mining fronts, through aerial images and the generation of a 3D model of the mine, where several information can be analyzed for blasting, routes for the vehicles, areas of risk, volume of material, among others. In safety matters, inspection routines may be conducted prior to dismantling operations to ensure that there are no people and vehicles in hazardous areas that may be affected by debris material projection during the blasting. Subsequently, after the blasting in the open-pit mine, UAVs can be used for rapid information acquisition with the mapping of the mining front.

The growth in the use of autonomous off-road trucks and vehicles within the mining areas requires reliability in data transmission systems. In this sense, adding signal receivers in UAVs allows the mapping of signal area of antennas and WiFi signal in the mining area, ensuring the quality of the communication between the equipment. Guarantee of good communication systems is essential for autonomous vehicles in the mine.

The autonomous off-road trucks and cars that run in the mines currently require a previous map with a high degree of detail and precision of the areas in which they can move. Before a new area of locomotion is enabled, in order to ensure that this area is safe and ready to be used, a driver usually goes to the location along with a support car and maps it with the vehicle sensors, passing through the place to be released. Although it ensures that unsafe areas are not released for autonomous vehicles, it depends on a human going to the site to do the mapping. In this aspect, UAVs can assist in this work of mapping and release of new areas, reducing the need for people to circulate in the mine areas.

17.3.1.2 Materials Transportation

Among the main applications of UAVs in industrial plants is the monitoring and inspection of material transport systems in all stages of the production process, both raw materials and processed products. One of the most used material transport equipment is conveyor belts, which can reach tens of kilometers in a single industrial installation. These systems require routine inspections, often at remote and high locations. These characteristics highlight the possibility of using UAVs to perform tasks in these equipment, and several researches have been done in this field [5], using many different sensors for this task of inspecting the conveyor belt structure and the rollers.

For long distances, some companies use the transportation carried out by pipelines. In this case, the UAVs can assist inspection operations in remote areas (similar to oil and gas pipelines [6]), being part of the set of equipment transported in support cars for inspection routines.

Monitoring routines in logistics systems for material transport, such as railway inspections [7, 8], can benefit from the use of UAVs carrying sensors for analysis and maintenance of the permanent way.

17.3.1.3 Processing Plant

At processing plants, UAVs are currently used for volume measurement in ore piles [9], inspections, and data acquisition at heights. They can contribute with routine inspections, corrosion, and cracks analysis in building structures, bridges, towers, antennas, large equipment, among others.

17.3.1.4 Dams and Reservoirs

In both water and tailing dams and reservoirs, the UAVs contribute to monitoring along the banks and points of interest, as well as periodic inspections of structures and sensors [10, 11].

Effluent monitoring systems can benefit from the implementation of autonomous sample collection in rivers and dams, using UAVs equipped with sample holders to acquire materials along a trajectory. This equipment promotes a flexible and agile collection, increasing the speed of analysis, from the water collection systems for the production process to the effluent analysis and monitoring of the water quality generated after the process in the industry.

17.3.2 Steel Industry

At steel industry, UAVs have been used in several areas throughout the production process, assisting in the acquisition of information from various industrial equipment during their inspection.

17.3.2.1 Raw Materials Yard

In the raw materials yard, one of the main applications of UAVs, besides aerial monitoring, is in the calculation of material volume in the stockpiles. With the acquisition of aerial images through autonomous flight and subsequent processing in a photogrammetry software, the amount of material in the cells is estimated with the required precision.

The same has been applied in scrap yards, scanning the area and estimating the volume of material in the piles, which are usually separated by piles of materials with similar chemical composition.

17.3.2.2 Material Transportation

The materials transport systems at steel industry are very similar to those of mining, mainly composed of rail transport, conveyor belts, and cranes, according to Sect. 17.3.1.2.

The main difference is that in the steel industry, monitoring the temperature of the transported material is a very important information for the production process. Therefore, the use of sensors and thermal cameras in the UAVs provides the acquisition of very relevant data to the production process.

17.3.2.3 Blast Furnace

In the blast furnace area, the UAVs have already been used for structural monitoring, and image acquisition of the pipes in height.

One of the major health risks for people who move around the structures near the blast furnace is the leakage of carbon monoxide (CO). The monitoring and mapping of possible leaks of toxic gases can be done using UAVs equipped with sensors to detect these gases, avoiding the risk of poisoning accidents.

Mechanisms that can benefit from the use of UAVs for routine inspection are the bleeders, which are pressure valves located at the top of the blast furnace, aimed to relieve the high pressure inside of it. As it is a high-risk area for people, the use of equipment for monitoring and inspection brings great benefits.

With the use of thermal cameras, it is possible to map potential structural problems in the blast furnace and in the pipes, both in the heated oxygen pipes from the regenerators for injection in the blast furnace by the tuyeres, as in the exhaust gases pipes at the top of the blast furnace for the cyclones and gas cleaning systems.

17.3.2.4 Steelmaking

Primary and secondary steelmaking, continuous casting, rolling, and other subsequent processes in the steel industry usually occur within large enclosed sheds. Although much more limited, the indoor use of UAVs can also enable the acquisition of information and inspect assets in height. In this complex environment, the most common is to use navigation based on vision systems.

As examples of UAVs, applications in indoor areas, inspection on cranes, winches, etc., as well as corrosion analysis in the structural part of equipment and buildings can be carried out. In addition, it is also possible to perform small tasks inside buildings, in the lighting systems, and sensors in high places.

17.3.3 Cement Industry

In the cement industry, much of what has been discussed in the previous sections on the use of UAVs, in various applications and areas, can also be applied in a quite similar way because of the similarity of much of the equipment throughout the production process. In this sense, application can be related to the entire production and supply chain, such as those of the mining industry: mining; storage of raw materials; production systems; and transportation.

Thermal analysis in height can be made in the heat exchangers in the preheating tower and in the rotary kiln for the production of clinker. It is possible to identify potential sources of issues by temperature variations, indicating areas of erosion, wear, corrosion, refractory collapse, among other common problems.

The monitoring to control the emission of polluting gases can also be done with sensors coupled to the UAVs, contributing to meeting environmental standards along the production chain.

17.3.4 Energy Industry

Numerous applications of UAVs are already in use in the power generation and distribution industry, from structural inspections on offshore oil platforms to the ethanol industry, with monitoring of sugarcane plantations. It also includes the use of UAVs for inspections in chimneys and gas pipelines, monitoring gas leak detection, corrosion, exposed pipes, erosion, among other possible issues.

In the electricity generation and distribution industry many applications can be found nowadays, several of them in the early stages of research, but still showing up as a very promising topic.

17.3.4.1 Electric Power Distribution

The electric power distribution system has a grid with thousands of kilometers of extension, which periodically goes through inspection routines. Some of the data from these inspections can be acquired by monitoring using vertical take-off and landing (VTOL) UAVs, starting from support points or support vehicles and having a good coverage area in flight.

Among the applications in the electric energy transmission sector, it is worth mentioning the image monitoring and infrared (thermographic) camera in the transmission lines (LTs), in their connections and substations of energy. Moreover, structural and corrosion analyses in the towers contribute to reduce the risk of accidents.

An application that interests the concessionaires of transmission and distribution of energy is in the monitoring of vegetation overgrowth, controlling the vegetation under transmission lines.

17.3.4.2 Hydroelectric Plants

In hydroelectric plants, one of the main applications is routine monitoring in dams, performing actions similar to those described in Sect. 17.3.1.4. UAVs can be used for structural inspections at dams and spillways, detecting cracks, corrosion, and other potential issues in structures.

17.3.4.3 Thermoelectric Plants

Sensor-equipped UAVs have now been used for tower and chimney inspections in many industries, including thermoelectric power plants. When the production is stopped or reduced, inspections of the chimney coating can be made, being a much simpler operation than those involving human beings.

Monitoring the emission of pollutant gases can also be performed by UAVs, including mapping the area of gas dispersion in the region.

17.3.4.4 Wind Power Plants

In wind power plants, UAVs can assist height inspections in a very practical and efficient way. With various sensors, they can detect erosion, cracks, and other defects in blade surfaces.

Unusual but useful applications of UAVs come up every day, solving problems in a simple and practical way, like using an industrial drone to de-ice a wind turbine [12].

The structure of the generation tower can also be analyzed with sensors embedded in UAVs, performing inspection operations quickly and safely.

17.3.4.5 Photovoltaic

The giant farms of solar panels require constant inspection and maintenance of these panels. A single section of a damaged panel can completely hamper the production of that panel.

From aerial images with thermal cameras it is possible to detect faults in the panels in a simple and agile manner, reducing the losses of energy generation by defects in the panels.

17.3.5 Agriculture

One of the first applications of UAVs in the industry occurred in the agriculture sector, initially with acquisition of simple aerial images, and later with multi-spectral cameras and other tools of remote sensing and monitoring of the plantations, allowing a fast and efficient control in all phases of the plantation cycle.

Several studies have been developed with applications of UAVs for precision agriculture [13, 14].

The identification of affected areas for pest control in large plantations can be aided by information acquired from aerial images. On a small scale, the control itself can be aided by the localized spray of pest control products by UAVs.

17.4 Conclusions

Nowadays, the influence of UAVs is evident, which becomes clear with the great diversity of applications and researches in progress in many different areas. The growing trend of UAVs usage is also evident due to the gains made with its applications, enabling the acquisition of information in a fast and flexible manner and performing tasks without the need of human involvement.

Undoubtedly, the UAVs will play a fundamental role in the everyday life of the smart cities, urban areas, and industry, contributing to the improvement of the quality of life in its most different aspects.

In the industries, the UAVs contribute to the acquisition of data about the productive processes and the detection of leaks, security, and potential sources of issues. For long-distance monitoring and inspection, the trend is for fixed-wing UAVs, or VTOLs, which can take off from suport cars in the regions of inspections.

Therefore, UAVs can bring numerous advantages, but all this will only be possible if adequate rules and legislation are developed, controlling their use in a way that can contribute to society.

Acknowledgements The author would like to thank the CAPES / ITV support—call 20/2016.

References

1. Valavanis, K.P., Kontitsis, M.: A historical perspective on unmanned aerial vehicles. In: Valavanis, K.P. (ed.) Advances in Unmanned Aerial Vehicles. Intelligent Systems, Control and Automation: Science and Engineering, vol. 33. Springer, Dordrecht (2007)
2. Mora, L., Bolici, R., Deakin, M.: The first two decades of smart-city research: a bibliometric analysis. J. Urban Technol. **24**(1), 3–27 (2017). https://doi.org/10.1080/10630732.2017.1285123
3. Giffinger, R., Ferter, C., Kramar, H., Kalasek, R., Pichler-Milanovic, N., Meijers, E.: Smart cities: ranking of European medium-sized cities, report from Centre of Regional Science, Vienna (2007)
4. Freire, G.R., Cota, R.F.: Capture of images in inaccessible areas in an underground mine using an unmanned aerial vehicle. In: Hudyma, M., Potvin, Y. (eds.) Proceedings of the First International Conference on Underground Mining Technology. Australian Centre for Geomechanics, Crawley (2017)
5. Nascimento, R., Carvalho, R., Delabrida, S., Bianchi, A., Oliveira, R., Garcia, L.: An integrated inspection system for belt conveyor rollers - advancing in an enterprise architecture. In: Proceedings of the 19th International Conference on Enterprise Information Systems V.2: ICEIS, pp. 190–200 (2017). ISBN 978-989-758-248-6. https://doi.org/10.5220/0006369101900200
6. Gomez, C., Green, D.R.: Small-scale airborne platforms for oil and gas pipeline monitoring and mapping. UCEMM - University of Aberdeen Report (2015)
7. Flammini, F., Pragliola, C., Smarra, G.: Railway infrastructure monitoring by drones. In: 2016 International Conference on Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles & International Transportation Electrification Conference (ESARS-ITEC), France (2017). https://doi.org/10.1109/ESARS-ITEC.2016.7841398
8. Wu, Y., Qin, Y., Wang, Z., Jia, L.: A UAV-based visual inspection method for rail surface defects. Appl. Sci. **8**, 1028 (2018). https://doi.org/10.3390/app8071028
9. Raeva, P.L., Filipova, S.L., Filipov, D.G.: Volume computation of a stockpile - a study case comparing GPS and UAV measurements in AN open pit quarry. In: XXIII ISPRS Congress, Czech Republic (2016). https://doi.org/10.5194/isprsarchives-XLI-B1-999-2016
10. Ridolfi, E., Manciola, P.: Water level measurements from drones: a pilot case study at a dam site. Water **10**, 297 (2018). https://doi.org/10.3390/w10030297
11. Wang, K.L., Huang, Z.J.: Discover failure mechanism of a landslide dam using UAV. In: ICCCBE2016 16th International Conference on Computing in Civil and Building Engineering, Japan (2016)
12. Aerones: Wind turbine de-ice (2018). https://www.aerones.com/eng/wind_turbine_maintenance_drone. Cited 16 Oct 2018
13. Zhang, C., Kovacs, J.M.: The application of small unmanned aerial systems for precision agriculture: a review. Precis. Agric. **13**, 693. https://doi.org/10.1007/s11119-012-9274-5
14. Mogili, U.R., Deepak, B.B.V.L.: Review on application of drone systems in precision agriculture. Procedia Comput. Sci. **133** (2018). https://doi.org/10.1016/j.procs.2018.07.063