THE USE OF UNMANNED AERIAL VEHICLES FOR MONITORING PURPOSES IN CIVILIAN APPLICATIONS

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Abstract: *This paper aims to present some of the applications that are currently using Unmanned Aerial Vehicles (UAVs) for monitoring activities in the civilian sector. The domains of use that are detailed in the article were chosen specifically because UAVs have a significant contribution to the increase of their productivity. Each of them is presented in order to highlight the high complexity of the monitoring activities involved, the disadvantages of the methods that are currently in use, as well as the benefits of using UAVs for these tasks. Furthermore, the methods that are most commonly used and have achieved the best results in the researches conducted in the field are mentioned and reviewed.*

Keywords: *unmanned aerial vehicle, monitoring in civilian applications, crop monitoring, wildlife monitoring, infrastructure inspections*

1. INTRODUCTION

An unmanned aerial vehicle (UAV) is a type of aircraft that does not have a human pilot on board [1]. Due to the recent innovations in this domain and the large number of applications, UAVs may be seen as a modern invention, yet their origins are back in the First World War, when the first pilotless aircrafts were developed. The very first radio-controlled pilotless drone was the British Aerial Target, followed after a short period of time by the Kettering Bug, an American aerial torpedo [2, 3]. In the period between the wars, there was a continuous development of the UAVs, with new models being developed and tested for military purposes. Nowadays, the applications of UAVs are various, ranging from aerial photography and filming to goods delivery, and search and rescue missions.

There are two types of drones: remotely piloted aircrafts (RPAs) that need to be remotely controlled by a human pilot, and autonomous drones that are controlled with the help of embedded software algorithms, without the intervention of a human operator. UAVs are a type of device that can be easily controlled by the use of a smartphone, are often equipped with cameras, different types of sensors specific to the application requirements, Global Positioning System (GPS) and communication systems. All of these are characteristics that make drones suitable to use in dangerous environments, time-consuming or repetitive monitoring tasks, or applications that require huge amount of data acquisition, being more reliable and efficient than a human being.

It appears to be a significant progress in the development of UAVs, with even more new capabilities and functions being implemented into these devices in the last period of time. The increase of the onboard processing power, battery life, and the improvement of flight control algorithms, together with the reduced size and weight of the new models, are extending the range of UAVs applications, making them suitable not only for military use.

In the following, several applications of UAVs in agriculture, wildlife monitoring, and infrastructure inspections will be discussed in order to indicate the advantages of using UAVs for activities that were previously done by humans.

2. AGRICULTURE

The agricultural system is one of highly importance for the economy of a country. Since early times, people have lived from the result of their efforts and hard work to cultivate large areas of land in order to provide food for their family and livestock. The output of the cultivated land, along with the animal-source foods, were also used in commercial scope, representing an important source of money at that time. Even if the purpose of the agricultural activities remains the same in our times, the techniques used in order to achieve the desired yields have changed, while the amount of the invested work, money, and time is majorly increasing. Due to the latest technological advances, most of the tasks involved by the agricultural activities can be automated, therefore reducing the efforts made by the farmers, and the negative effects of the climate change and environment conditions on the agricultural output. The recent booming of UAVs, that have become an easy-to-use and affordable device by the general population, makes them an efficient method of field monitoring. UAVs have played a major role in the evolution of a concept named precision agriculture, which aims to develop a system in which decisions can be remotely taken by humans, based on the information resulted from land monitoring performed by drones [4, 5]. Consequently, the most meaningful applications of UAVs in the agricultural industry, that result from field surveillance, include crop health monitoring and soil conditions monitoring.

In order to determine if plants are healthy, or they have been affected by diseases or pests, fields must be carefully examined by farmers. They are searching for changes in the color and shape of the leaves, which indicate that actions must be taken to save the plant. If the process of field monitoring is performed by human operators, it is time consuming and prone to error. Therefore, a commonly used method of crop health assessment uses remote sensing. Aerial images provided by satellites, or UAVs equipped with sensors, such as multispectral or hyperspectral cameras [6, 7, 8], are further analyzed by algorithms to provide useful information to the farmers. However, plant monitoring using satellite images has a series of disadvantages, being highly dependent of the environment conditions, such as cloud cover and available amount of light. Also, accessing satellite images is expensive, and the gathered images have low resolution and quality. The need for higher resolution spatial and temporal data, that can be easily achieved using UAVs, has contributed to the spreading of drones in plant health monitoring. Some of the most frequently used and efficient image analysis techniques are using machine learning algorithms [7, 9, 10], or computation of the Normalized Difference Vegetation Index (NDVI). While the use of artificial intelligence algorithms is still under research and needs some improvements to become a reliable method of plant health assessment, systems based on NDVI are already commercially available [11, 12], being able to detect crop degradation from early stages, when changes are not visible to the human eye, or to spot weeds. Furthermore, the information obtained using this type of system is useful to determine the optimal quantity of herbicides, pesticides, fertilizers, or water that needs to be provided to specific areas of the crop field. NDVI indicates the health of the plant based on the reflection of the infrared light. The cellular structure of a healthy leaf reflects a lot of near-infrared light. The level of the reflected near-infrared light decreases if the plant is dehydrated or affected by diseases, while the amount of reflected visible light remains the same.

Based on this fact, plants can be differentiated from other surfaces, and diseases, pest infection, or dehydration can be detected [13]. Figure 1 illustrates an example of a NDVI map of a crop field.

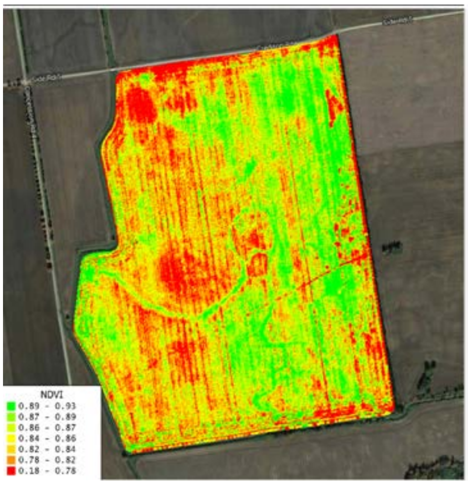

FIG. 1. Example of crop field mapping based on NDVI [14]

UAVs can also be equipped with other types of sensors, such as laser scanners, thermal sensors, or red-green-blue (RGB) cameras for enhanced field information [15, 16, 17, 18]. However, the data provided by those needs more processing operations and is not as useful in plants health assessment as the one provided by multispectral images. Moreover, satellite and UAV data fusion has been explored in [19], proving that increased performance can result from combining the high-resolution data provided by UAVs with information over large areas of land from satellite images.

UAVs equipped with the above-mentioned sensors can also be used to monitor field conditions. After data analysis or correlation of the data provided by sensors, information about soil moisture or irregularities in the field is obtained. This is useful for irrigation planning, with the aim to avoid water wasting or overwatered plants. Some of the researches that have been made in this direction are detailed in [20, 21, 22].

3. WILDLIFE MONITORING

The importance of wildlife monitoring comes from the need of endangered species conservation and, subsequently, the conservation of the ecosystem in which they are living, as well as the desire to know the impact of human actions or climate changes on certain species. Approaches of this problem that are using UAVs have appeared as a better solution than the already existing methods. Those are far too expensive and time consuming because some of the species that need to be monitored live in remote, rough or hard to reach areas, such as polar regions, desert or oceans, and helicopters or boats are required to reach them. Also, the use of UAVs to monitor the wild animals eliminates the process of implanting or attaching them monitoring devices for data collection, which is an invasive technique that affects the animal. In the field of wildlife monitoring, drones have applications in areas like assessing the health of the animals, counting and precisely locating them, or collect useful data for research purposes.

The methods that are currently used for wildlife monitoring generally depend on the size of the habitat and the density of animals in order to achieve the best results.

UAVs represent a reliable, noninvasive and safe method to collect samples from wild animals with the aim of monitoring the health of the animals. In this direction, several papers focus on collecting samples from whale species [23, 24].

Furthermore, a research that proves that UAVs can be used even in virological studies is [25], in which a drone was used to collect whale blow samples, thereby identifying six novel virus species. Figure 2 shows the process of collecting whale blow samples using an UAV.

FIG. 2. UAV collecting a sample of whale blow [23]

The information gathered about the size and the habits of wild animals is also the subject of a lot of biological studies. Drones equipped with cameras can be used to provide data for researchers, in order to make estimations on the body size or the condition of the animals [26], or to gather information about the behavior of the animals under certain conditions [27]. Another method that is commonly used for wildlife monitoring is called footprint identification technique [28]. It is able to identify individuals based on their footprints, using artificial intelligence and a database with footprints of other animals from that species. The efficiency of this technique was demonstrated in [29, 30].

In the same way as plant health monitoring, wildlife population surveys are also driven by remote sensing techniques, aided by image analysis. At the moment, a homogenous background is necessary for the automated image analysis algorithms to obtain results that are comparable to the human counting of the specimens. Most of the experiments on counting animals through the use of drones are conducted in homogeneous landscapes and focus on large bodied species of animals [31] or birds [32], proving that even more accurate results are achieved using automated counting of the animals, compared to the method that uses people to count animals [32, 33]. The recent developments in artificial intelligence have significantly contributed to the improvement of drone-based wildlife surveys, machine learning algorithm being used to detect the animals [34, 35]. In the same way, drones can be used for livestock counting, that represents a more challenging task because of the diversity of the landscape in which domestic animals are living [36]. It has been demonstrated that thermal and infra-red cameras need to be used to achieve better results in the case of heterogenous landscape [37, 38].

4. INFRASTRUCTURE INSPECTIONS

Infrastructure inspections are a mandatory task that guarantees the functionality and the integrity of a system, as well as the safety of the workers and environment protection.

Some of these activities involve dangerous working conditions for the inspector, such as climbing in harsh weather conditions, working near highly flammable gasses or in toxic environment. Furthermore, in some industries, plant shutdowns are required to be able to analyze parts of the infrastructure that are inaccessible during operation.

The shutdown time involves revenue losses for the company, that can be avoided using drones for inspection. Also, by eliminating the need of shutdown planning, inspections can be conducted more frequently, resulting in increased safety of the equipment. As a result of the difficulties involved by the traditional methods of inspection, drones are becoming a very popular alternative in the domain of infrastructure monitoring. Most of the inspections carried out in this field are performed by UAVs equipped with cameras that collect data about the equipment. The information gathered by drones is then visually reviewed by specialized people or by artificial intelligence algorithms, with the scope of discovering the areas that need intervention. In the following lines, some of the uses of UAVs for infrastructure monitoring are detailed.

Oil and gas pipelines need to be frequently analyzed to discover potential signs of corrosion or leakage that might lead to an environmental disaster. The substances that result from oil and gas extraction lead to pollution of the environment in the extraction area, that has irreversible consequences for the plants, wildlife, and the human population that lives in the region. As a consequence, pipelines are often placed in remote, uninhabited areas, spreading over vast regions, which makes them very difficult to inspect. Most of the methods used to detect a potential leak using UAVs are based on laser detectors, that measure the absorption of the transmitted beam in order to detect the presence of methane [39, 40, 41]. Figure 3 shows the diagram of the methane detection system implemented in [41]. It sends an infrared laser beam to a surface, concentrates the reflected beam onto a photodetector, and converts the received laser power to an electronic signal that is processed in order to determine the presence of methane.

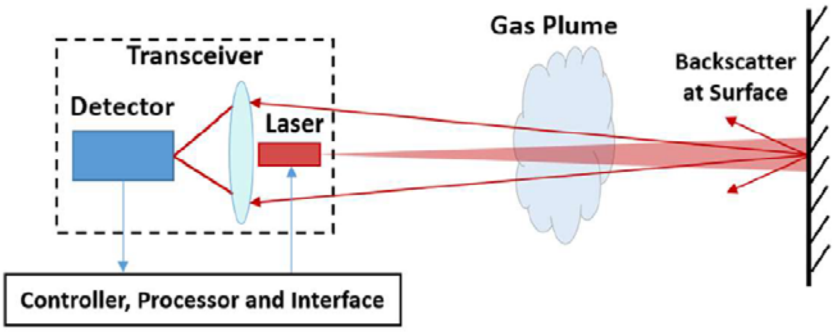

FIG. 3. The operation of the Remote Methane Leak Detector used in [41]

Regarding the oil and gas industry, the storage tanks are another element that requires periodic inspections. Wall-sticking drones, that are able to inspect containers and collect data using onboard sensors [42], prove the capability of using UAVs in the oil and gas industry not only in combination with visual inspection methods.

Mandatory regular inspections of the power lines are currently performed by humans that climb the poles of the distribution lines or by helicopters, and involve a huge risk due to the high-voltage of the transmission lines.

The use of drones equipped with cameras, that are able to record or transmit visual information, reduces the time and the risks of human inspections, as well as the increased cost of inspections performed by helicopters. Besides daylight cameras, sensors that acquire thermal information, as in [43, 44], are a commonly seen payload of the drones in order to detect hot spots that reveal damages on the cables and insulators, resulting in areas with increased temperature [45].

An industry that is in continuous expansion is represented by the renewable energy. The use of wind farms to produce electricity is safe for the environment, reducing the pollution, and uses as source of energy a free and widely available resource of the nature. Wind parks are often placed in regions that are hard to reach and very extended, and the task of monitoring wind turbines is challenging because of their increased height.

The blades of wind turbines are the most affected element, being permanently exposed to high loads and to weather conditions. Photos taken from the ground, inspectors moving using service platforms, or going down on a rope are the methods that are currently used to inspect the blades of wind turbines. Those are able to detect only visible damages at the surface of the blade. Thereby, drones are a tool that can be very helpful in order to assess the condition of wind turbines. The most addressed subject in the researches that have been made in wind turbines monitoring is assessing the condition of the blades. They are able to automatically identify structural damages on the surface of the blades using convolutional neural networks [46, 47], or to detect internal damages using crawling robots that perform ultrasonic inspections and drones equipped with infrared cameras and LiDAR to precisely locate the damages [48].

Another type of renewable energy that requires permanent inspections of the infrastructure in order to avoid losses in the output power of the plant is the solar energy. The most common defects of the photovoltaic modules are detectable by visual inspections and include delamination, corrosion, cracks or snail trails, that lead to a decrease in the energy produced by the panels. An example of a snail trail detected by image processing algorithms is shown in Fig. 4.

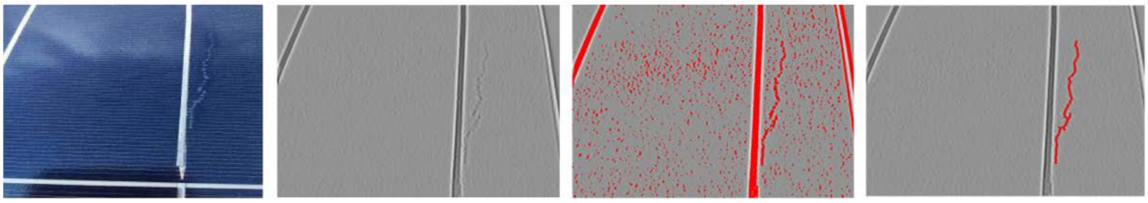

FIG. 4. Detection of snail trails using image processing algorithms [50]

Another commonly used method to detect defects and failures of the photovoltaic modules is called thermography. It uses thermal infrared sensors to observe the temperature regions from the surface of the cell that indicate electrical failures, hot spots or micro-cracks [49]. Researches that have been made using UAVs for the inspection of the photovoltaic systems focus on the automatic detection of the defects through visual inspections using high-resolution cameras and image processing algorithms [50], or in combination with thermography [51, 52].

CONCLUSIONS

There are many activities and industries that require either permanent inspections of the assets in order to achieve the expected output, or the monitoring of remote life and activity to collect useful data for research purposes. This process is often manually performed by humans that are put in dangerous working conditions and is significantly time-consuming and inefficient, while the existing alternatives are very expensive. The continuous improvements of the technology used for drones, that made them more stable, easy to control, lightweight and increased their flight time, makes them an inexpensive and more efficient tool that is able to handle this task.

Furthermore, the possibility to carry different onboard sensors or cameras, and to embed image processing or machine learning algorithms provides more quantitative and qualitative information on the inspected elements. These, together with the recent developments that have been made in the field of artificial intelligence, which is able to eliminate the use of human operators for image analysis, are promising the development of a completely automated, stable and efficient solution for monitoring in the immediate future.

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