Smart drone imaging applications

Prashant Kanade[1], Pragya Choudhary[2], Ria Dharmani[3], Archana Bhatia[4], Mohini Bhave[5]

[1]Professor, Dept. of Computer Engineering, Vivekanand Education Society's Institute of Technology, Maharashtra, India

[2,3,4,5]Student, Dept. of Computer Engineering, Vivekanand Education Society's Institute of Technology, Maharashtra, India

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Abstract - *This is a survey paper that highlights some of the interesting applications of the swarm of drones in various fields. The paper explains the need and challenges associated with various application areas of swarms.*

***Key Words*: drones, unmanned aerial vehicles, swarm, applications, search and rescue operations, pipeline maintenance, construction.**

1. INTRODUCTION

Drones, also known as Unmanned Aerial Vehicles (UAVs) or Remotely Piloted Aircraft (RPAs), are becoming increasingly popular in recent years. Be it their usage for delivering products, or media coverage, or simply their use for spending leisure time by an individual, they are coming into vogue everywhere.

Swarms of drones, instead of a single vehicle, is the next level of automation in drone technology. This paper provides the cumulative work from a survey that focused on identifying the potential applications of the swarm of drones in various fields by different researchers.

The subsequent sections are arranged as follows: Section 2, highlights the drone applications in the field of pipeline maintenance. Section 3, describes the usage in Search and Rescue (SAR) operations, along with providing the summary of an important algorithm proposed by other authors in 4. Section 5, gives the idea about the use of swarms in the construction industry.

2. APPLICATIONS IN PIPELINE MAINTENANCE

Oil pipelines cover vast infrastructures often in harsh terrains such as marshlands, hot deserts or frozen areas, or even areas of conflict. The length of pipelines in Russia exceeds 280 thousand kilometers while in America it exceeds 2.2 million kilometers. Vast layouts of the world's most essential resource make it vastly difficult to identify leaks. In case leaks/ damage goes undetected it not only results in loss of resources it causes irreparable damage to the natural environment [1]. Some traditional methods to detect pipeline leaks are as follows:

2.1 Physical Patrolling

Without appropriate equipment it is difficult to detect leaks visually, or by smell. Human inspections can have limitations when it comes to heights or confined spaces. These inspections are more often than not constrained to predetermined routes based on statistical sampling, leaving certain pipeline areas un-inspected.

2.2 Pressure control method

Difficult to detect small leaks whereas large ones can be administered.

2.3 Ultrasonic flow meters

Difficult to sense small leaks. Additionally, it can prove to be expensive.

2.4 Conductive cables

Difficult to detect small leaks, moreover it is an expensive method.

2.5 Helicopter or Plane

Manned aerial navigation flies higher and quicker and has to carry heavy and expensive monitoring equipment. Although, it still provides comparatively low-resolution images for the same money. The cost of the pilot is an additional expenditure.

2.6 Earth remote sensing data (Via satellites)

Low-resolution images are obtained that are difficult to analyze.

The conventional methods that are being used for pipeline maintenance are not only extremely time-consuming and economically unviable, but also dangerous to conduct. This can mainly be attributed to the widespread pipeline network, which is more often than not installed in places that are physically inaccessible. Unmanned Vehicles offer an ingenious solution to this problem. They are easily available, can navigate harsh terrains, and easy to operate.

Using drones provides several advantages to the industry user including the ability to maintain and operate a large fleet of aerial platforms, reduce the cost of operation, faster turnaround time, flexibility to perform some roles, higher quality inspection due to its ability to fly closer to the source and safety of operation. However drones can only perform an external inspection when a sample check may be required, platforms are susceptible to weather conditions and high winds. On average a UAV flight duration can range from thirty minutes to a couple of hours, having a restricted flight endurance.

In spite of the drawbacks delineated the usability of drone operations and their cost-effectiveness far outweigh their limitations. In various combinations, the above technologies can be used in the following methods for drones in pipeline monitoring [2].

- Multispectral imagery to identify: Can be used in an agricultural space to detect plant health, but conversely, it can be used to see the effect of pipelines on the ecosystem and identify gas leaks.
- Lidar to create a 3D digital model: Lidar models are exceptionally accurate. Digital twins of the pipeline can be created and its relation to the first digital model of when the pipeline was installed to work out where the pipeline has shifted to after time and predict possible damage and modify pipeline to pre-empt damage that can occur [2].
- Helicopter or plane: General wave cameras using RGB imagery and thermal overlay can predict weaknesses in pipes and possible leaks and send out inspection teams to measure if an actual leak or a bigger heat shift is reflecting structural failure.

3. SAR OPERATIONS AT SEA

The authors in [3] are focusing on United Nations' Sustainable Development Goals and hence, providing a tech-savvy solution to the problems of migrants. The aim is to apply Artificial Intelligence and Robotics for search and rescue(SAR) operations at sea, that is for solving the crisis of the migrants crossing the Mediterranean sea. Current solutions have human experts based on the ground who are operating the aerial vehicles and also detecting emergency situations.

The focus is now shifting to the usage of unmanned vehicles for reducing cost and increasing the efficiency of these SAR operations. But a single UAV with limited battery life and unreliable communication capabilities can only cover a small area. It also lacks autonomy in operation. And this is where an autonomous swarm of intelligent UAVs will come to the rescue. To tackle the limited battery lifetime, a required number of self-organizing UAVs will cover a large area in less time. To improve bandwidth utilization, a multi-hop communication system will be better because of its increased aerial links and direct Line of Sight (LOS) in the air. The detection tasks can be enhanced by exploiting the recent efforts in AI such as specialized AI chips and quantization/pruning techniques. However, the harsh sea environments and unavailability of landing ports may pose a challenge in implementing these solutions, solutions of which are left to future research and development.

4. SWARM NAVIGATION AND VICTIM DETECTION IN SAR OPERATIONS

The paper in [4] aims to shed light on the navigation technique and the establishment of consensus among the robots of a swarm for detecting victims in search and rescue operations. The authors propose a modified rendezvous consensus algorithm for determining the existence of a victim in a search area. The paper begins with their extensive research work describing the advantages of robotics and particularly of the swarm of robots for SAR and similar missions. Instead of using a single drone, such multi-drone systems prove to be useful for exploration of unknown areas, mapping the area, and finally searching and locating the victims. Since it is difficult to test the project in a real disaster environment, the authors have used software like MATLAB and V-REP for simulation. The paper presents three main steps for a SAR mission: developing a navigation system for the swarm, detecting a possible victim, and finally, establishing consensus among the sub-swarm drones.

4.1 Navigation process

The navigation rules are modeled using graph theory (V, E) with V representing the set of nodes or robots and E representing the topology of the system. These rules are applied to individual agents and the cumulative behavior of the swarm depends on the individual decisions of the drone agents. The navigation process is governed by the attractive and repulsive forces among the agents and their environment. The attraction parameter maintains the coherency of the swarm by keeping the agents close to each other, while the repulsion parameter allows them to be at a sufficient distance from each other. The repulsive force also helps to avoid the obstacles and hence, the collisions. The victims apply an attractive force on the nearby agents. Due to this, the agents in the proximity of the victim slow down, and at least one agent stops. This agent now sends a signal of victim detection, causing a disturbance in the rest of the network. This leads to the creation of a sub-swarm.

4.2 Victim detection and establishing consensus

A sub-swarm is a part of the main swarm detached for localization around the victim. The creation of a sub-swarm is handled with the K-Nearest Neighbor algorithm on the weighted graph. Say, node i is the first one to detect the victim. The neighbors of node i are selected using K-Nearest Neighbor to participate in the sub-swarm. The remaining agents of the main swarm can continue their search for other victims. To enhance the correctness and reliability of the detection, the agents of the sub-swarm use a rendezvous consensus mechanism to position themselves along a circle with the victim as the target center position. Since no agent is at a different distance from the victim, their individual decisions will be quite reliable. Each robot has the sensing capability, with the help of which the classification between the victims and the false positives can be carried out by the sensor network consensus. The authors in this paper have modeled the sensors using distributed least square error to cope up with the fact that real sensors are affected by the noise from the surroundings.

4.3 Simulation

A number of experiments were carried out using Matlab and V-Rep software. The experiments simulated the real world consisting of obstacles, people as victims, multi-robot systems, etc. They model the swarm behavior and victim detection using the techniques and algorithms specified above. Finally, the task of creating an algorithm that will inform the rescuers about the exact localization of people in disaster areas is left for future researchers.

5. APPLICATIONS IN CONSTRUCTION INDUSTRY

Many modern and conventional methods are used in the construction industry. There are various challenging problems throughout the cycle of construction projects that can be addressed with the help of Unmanned Aircraft Systems (UAS) effectively with the reduced time needed to accomplish tasks, improve safety standards, lower cost, and increase work quality. Also, with the use of thermal imaging, sensor technology, and photogrammetry with drones it has become possible to deliver quantifiable data about processes, materials, and personnel on-site data in less time and amount. Various areas of application of drones in the construction industry can be given as follows [5]–[7]:

5.1 Survey

Using drones can provide high-resolution images and overlapping photos can be put together in a mosaic which can be transformed into three-dimensional representations. They can be either DSM(Digital surface model) or DTM(Digital terrain model). Geometric information on actual construction site conditions can be obtained frequently with low error rates. Drones enable faster data collection, access to unreachable areas, high-quality data and reduces risks associated with surveys. Also, surveying areas like bridges, highways, railways, dams, etc in real-time is enabled using drones. This real-time actionable and in-depth data aids in decision-making. Vertical and oblique aerial images of rooftops can also be obtained.

5.2 Monitoring of construction activities

It is not possible for experienced contractors to stay on-site throughout the project. Supervisors provide daily updates on the work done. Drones can be used for monitoring real-time work progress. This provides information to contractors about what work is pending to help make decisions about what changes are required. Architects working on large-scale projects can use UAVs to monitor work so they can handle many sites and ensure their smooth running.

5.3 Visual inspection of hard-to-reach locations for defect and damage detection

Pilots with experience in drone usage can use drones to identify any construction or technical problems on-site. It gives easy access to collect data from inaccessible areas like the bottom of the bridge, Top of buildings, busy highways, etc. without additional safety risks to personnel. Any errors during the operation and maintenance period can be obtained along with records. Defects in structure can be identified by providing high-quality data. It also helps to detect water infiltration, leaks, and areas with mold or rot before they cause serious damage.

5.4 Safety and security monitoring

Construction workers are exposed to accidents that lead to financial losses, casualties, or disabilities. The use of UAVs can enhance construction practices and facilitate safety inspections of sites. They can also be used to immediately alert operators to the accident location and injured workers' information. Visual data collected can enhance safety inspection through improved visualization of working situations. Security during the night can be enhanced with help of thermographic cameras by providing aid in detecting hiding burglars using heat signatures collected from drones.

5.5 Aerial photography and topographical mapping

Drones provide a bird's eye view of the site which is typically used for aerial photography to provide photos and videos. UAVs with GPS technology are used to capture images from the same aerial perspective with predetermined waypoints to track progress against planned progress. For large and complex construction projects, consultation of topographical maps is required. A large amount of data can be captured in a relatively small time here with drones.

5.6 Equipment tracking and automating

Automating and equipment tracking is a problem for project managers on the construction site. Using drones the manager can immediately assess if the equipment is at its desired location during flight. Also devices that have already completed its work are there on site then it can be assessed with this to avoid expensive accidental extension charges.

5.7 Interaction with workers

UAS provides safety managers live contact with workers through a communication tool, including audio and video transmitters. It is very helpful as it provides workers with live feedback.

5.8 Documentation and making decisions

Documentation is an important part of infrastructure projects. It is required to show clients work progress, to clear bills. Taking real-time video and images is one of the best ways to do it.

5.9 To show progress to the client

Projects are funded by clients, so it is important to show them regular progress to get finance. Regular progress reports may be daily, weekly or monthly to get an idea about project progress according to the needs of the client. Such reports can be easily shown with drones without actual visits to sites by showing them films of work to avoid interference of clients in work.

5.10 Integration of laser scanning location and aerial photogrammetry

To gain access to suitable laser scanning location drone technology with laser scanning is used. Two stages are involved - Selection of the complete facade of the building for laser scanning and selection of complete roof the building for photogrammetry. Photogrammetry converts 2D images to 3D models through the use of triangulation with high-quality images. With the use of photometry with Lidar (Light detection and ranging), we can produce 3D models and contour maps for volumetric surveys.

5.11 Thermal imaging recording

It is possible to create aerial thermal images from different parts of the buildings to identify cold spots in buildings. It brings necessary information about the building in case it is essential to identify and rectify building defects. Thermography allows to determine thermal technical properties and detect hidden defects with considerate accuracy if evaluated correctly. It can also be used in security as mentioned above using thermal imaging mapping.

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