Extended Abstract: UAV System for Fire Assessment Using Custom Sensor Fusion

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Abstract - Urbanization will entail more building fires in the future. A low-cost UAV system is presented that would support municipal firefighters their operations, even when limited in their resources. The feasibility of a sustainable design is studied in developing a prototype. Custom data processing techniques are applied to reduce costs, and the results of the study are presented in terms of the specifications ultimately met by the prototype.

Index Terms - UAV, fire response, sensor fusion

I. Introduction

Cities around the world will soon have very high densities as the world's urban population increases, especially in developing nations. Many urban planners have predicted this will lead to future cities having more skyscrapers and taller buildings [1]. Without any significant changes in design, one can expect that the increased complexity and number of people in these structures will worsen existing hazards, such as fire.

Urban fire is a humanitarian issue not simply because fire affects cities worldwide, but also because municipalities in less developed countries are not able to respond as effectively. Compared to countries such as Canada where building codes to prevent fires are quite strict, other nations do not have these standards [2]. Limited resources also lead to difficulties for the local fire departments [3]. These realities call for an easy-to-use technological solution that is affordable for all fire crews.

Unmanned aerial vehicles (UAVs) and their surrounding technologies have made new lifesaving systems possible, including for firefighting. UAVs are a particularly suitable platform for urban fire detection given that their on-board data acquisition technology can be customized and their mobility enables fast response. They can be used to supplement the existing inspection performed by the first-arrived fire officer, which is subject to visual limitations of smoke and building height. There are few such UAV systems in use today since the standards for life-critical systems imply expensive sensors, as suggested by the case given in [4]. However, if made affordable and easy to maintain, a UAV system could become a good long-term investment for communities where some low-cost supplement for firefighters is important or reliability standards are less strict.

II. Objectives and Specifications

The objective of this student team project at Carleton University was to assess the feasibility of such a UAV system by attempting to develop one. The main requirements of this system were defined as follows:

1. Conduct a 360-degree flight path around the reported building, to assess in a safe manner
2. Collect customizable sensory information
3. Process and deliver data of fire location, hazards and human presence

In attempting to build a feasible prototype, the data from sensors in this project was limited to still imagery, heat detection data and smoke density data; these types of data are considered most essential to fire investigation. It was desired that the prototype remain within a student budget, as this would conceivably be affordable and maintainable even for a fire department with limited resources ($1000).

From consulting with municipal fire departments, such as the Ottawa Fire Services, as well as researching building fires, specifications of the design were set. Key metrics for a fire include the ability for the system to collect sensory data at long range from the hazards (at least 20m), collect sufficient data for initial decision-making (at least 5 minutes of flight time), and to provide real time data (1 Hz).

The system was also required to not collide with objects, which would cause more harm than help. For this reason, obstacle avoidance through obscurants was an objective.

III. Design Methologies

The design was done with a trade-off between cost and performance of fire detection. To this end, a low-cost design approach was taken: using only hobbyist electronic sensors in the design, and applying data processing in software to compensate for their limitations. This approach first involved selecting sensors that met the requirements and were also accessible to non-commercial users for easy replacement. For example, instead of using high-cost FLIR cameras that are able to detect through smoke and with high resolution, it was decided that a low resolution thermopile array (16x4 elements) would suffice to locate fire given the large scales involved. Similarly, an expensive (high-power) radar solution was not used for the obstacle detection through smoke in this application when it was found the power output was necessary for sufficient range.

After selecting the sensors, the approach also involved a form of sensor fusion in software to overcome the limitations of complementary low-cost sensors. This involved the development of algorithms to allow for selecting the best sensor measurement or a combination, depending on the case. Most importantly, this was done to detect objects through smoke using the combination of inexpensive lidar (smoke-limited) and ultrasonic (range-limited) sensor modules, rather than radar. Appropriately, the lidar data was used for long-distance targets and ultrasonic for short-range ones. For grey cases such as long-distance targets with smoke being present, moving mean filtering of lidar data and subsequent weighted averaging of lidar and ultrasonic data was done for better estimation. Such algorithms were applied to the smoke density determination too. On the other hand, to improve the ability to identify objects underlying the low resolution infrared images, actual image fusion was done with an optical image obtained from a separate camera. In this way, specialized sensors could be replaced by inexpensive ones.

The system itself was designed as shown in Fig. 1, with a low-cost computer (Raspberry Pi) used to collect and relay the sensory data. A graphical user interface (GUI) was developed to allow the firefighters to easily view the received data, enabling them to make fast decisions.

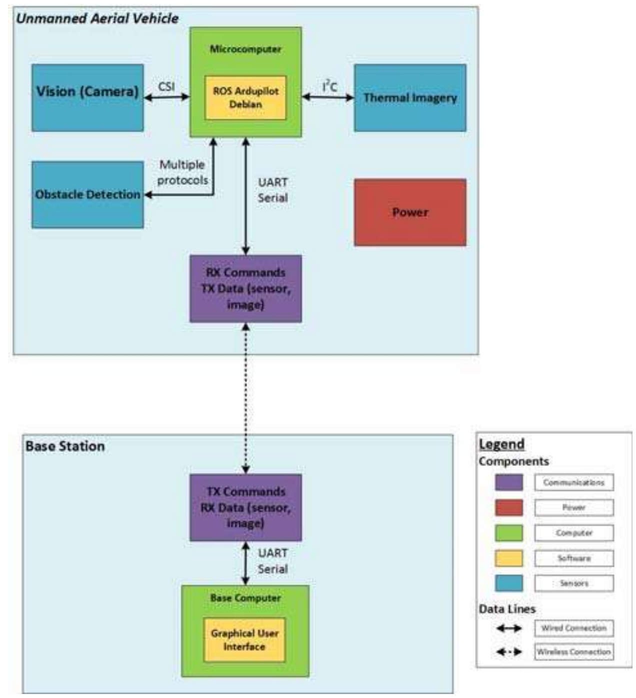

FIGURE 1: SYSTEM DIAGRAM OF REALIZED UAV SYSTEM

IV. RESULTS

Testing shows that the system is able to detect obstacles of up to 20m and at least 3.5m even with smoke present. It is also able to determine relative concentrations of smoke relative to clean air (10-bit resolution). The image fusion allows for distinguishing hot objects, down to approximately 20°C difference relative to their surroundings. However, the UAV system is currently limited to a flight time of 4 minutes and 40 seconds.

V. CONCLUSION

This paper has described the near feasibility of a UAV system for fire response, from design to the subsystems for a prototype. Though it may not be possible to bring this preliminary version to the level of a life-critical system for firefighting within limited resources, with further development it could become a supplementary tool for firefighters.

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