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An Application Layer Protocol to Support Cooperative Navigation of Multiple UAVs Systems

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Abstract: Applications involving multiple UAVs have gained increasing relevance in recent years, due to the benefits that cooperative systems tend to provide to their applications. In addition to performing several simultaneous tasks, the time spent to perform a certain task is reduced. In this article, an architecture for sharing navigation information is demonstrated to support applications composed of systems with multiple UAVs.

Keywords: Multiple UAVs, Data Sharing, Cooperative Systems

1 Introduction

Unmanned aerial vehicles (UAVs) are vehicles that can operate with different degrees of autonomy and can be disposable or reusable [NKYB13]. Its increasing popularity is related to the number of proposed applications that use sensor data, integrated into its mission control channel, to improve its navigation skills [AMG+18, KN17].

Cooperative systems, can perform missions in unstructured environments and achieve the mission objectives, with distributed computational cost and reduced time, benefiting from greater precision and efficiency, caused by their heterogeneous resources, in addition to better accessibility and robustness in the mission [ZLZ17].

For these autonomous cooperative navigation systems to work in completely unknown environments, it is of utmost importance that they can collect and store environment information efficiently so they can be used as a source of knowledge to create their trajectory during the mission which is destined to fulfill.

These experiences are stored in the form of maps that need to be shared with group members of the cooperative system so they can integrate these experiences into a unique and more reliable knowledge base. A new approach to share this information is needed [VP20, YSY+18]. In the approach presented in this work, the maps are compressed and then shared with the members of the group that are within the range of communication.

2 Approach Overview

The idea behind this work is to provide the information sharing infrastructure to support a cooperative navigation system composed of multiple UAVs. Figure 1 demonstrates the proposal's architecture. In this system, data is collected by sensors and transformed into grid maps. These, in turn, are the only information shared among the other vehicles that compose the network. The shared information is used to incorporate local information and then give the vehicle a sense of the global experiences obtained by the group.

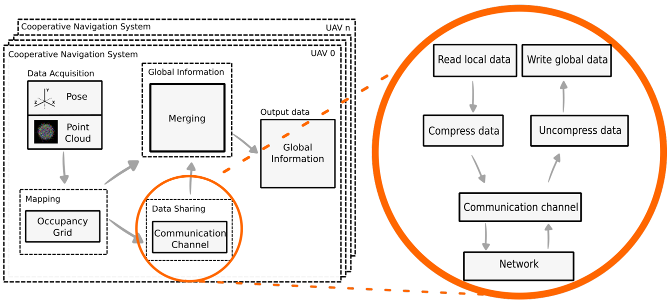


Figure 1: Integrated architecture of the information data sharing system.

The sharing of local maps is performed by the data sharing module (highlight in Figure 1) whenever two or more vehicles are within the communication range. In this module, local data is collected, compressed, serialized, and divided into blocks of 256 bytes of size per message. After, the messages are sent to the other nodes in the network through TCP protocol under an exclusive communication channel composed of IEEE 802.11ac modules. In this work, the shared data is composed of occupancy grid maps, stored in memory in one-dimensional structures (1D) using the *row-major order* indexing method. This storage method allows a compression technique to be applied to compress the maps before sharing. The proposed compression method is more simple than the conventional methods and takes into consideration the map data characteristics, consumes little computational resources, and it is suitable for embedded systems. An example of this technique is shown in Figure 2.

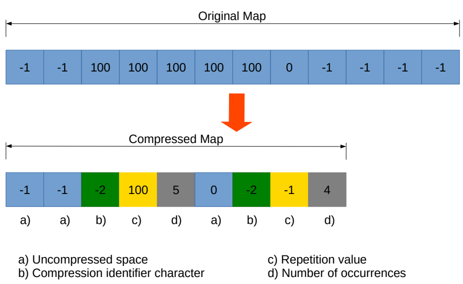
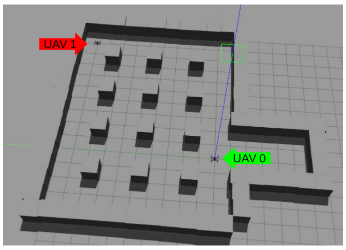


Figure 2: Example of map compression algorithm.

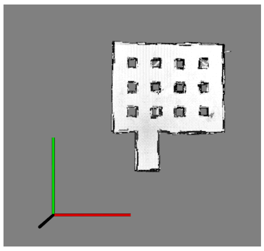
The used compression method identifies sequences with more than three repetitions and then replaces the sequence with three elements that have the function of representing the sequence. The compression identifier element identifies that there is the beginning of a sequence (Figure 2 b). The following elements (Figure 2 c) identify the value contained in the cells of the sequence while the third element (Figure 2 d) identifies the number of repetitions in the sequence. Finally, the other elements (Figure 2 a) were not susceptible to compression.

3 Case Study Demonstration

To evaluate the effectiveness of the proposal, a shared simulation environment was created using Gazebo. This environment is shown in Figure 3a and has an area of 16 m × 14 m.



(a) Experiments scenario.



(b) Merged robot information.

Figure 3: (a) Case study simulation environment. (b) Resulting merged map.

In this simulation, two notebooks connected to the same network, running the same algorithm and simulation environment, but representing different UAVs in different locations of the scenario. The UAVs were manually piloted in each notebook using a joystick and the obtained local maps were shared using the approach proposed in this work. Figure 4 shows in four different moments a timeline of the information shared between the vehicles.

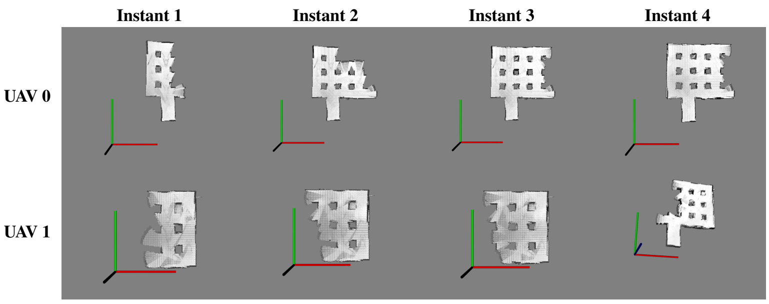


Figure 4: Timeline of information shared among UAVs during the tests.

After instant 4, shown in Figure 4, the algorithm responsible for merging the shared information converged in each notebook, and the result is the map shown in Figure 3b. Then, each vehicle has its own complete representation of the information obtained by the group and can use it to improve its navigation process, avoiding visiting regions previously visited by other vehicles, for instance. In summary, the global map is generated locally by each notebook and is available in both systems.

4 Conclusion

This work demonstrates a communication system used for information sharing to support cooperative navigation systems used in multiple UAVs systems. This approach is under development and is part of the studies developed for a Ph.D. thesis. This work presents the developed application architecture as well as the ideas and tools used for its development. Based on a case study, the first results obtained in this stage of the project are presented. As demonstrated, the application fulfills its function within the proposed architecture, but to improve the approach, an algorithm is needed to optimize the routes of the messages, reducing the traffic of network information, particularly considering groups with large numbers of members. Also, it is necessary to carry out tests with real vehicles so that it is possible to evaluate the influence of the vehicle mobility model on the transmission of data between them.

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