DISTRIBUTED COMMUNICATION AND CONTROL FOR MULTI-AGENT SYSTEMS: MICROINDUSTRIAL VEHICLE ROTORS (MAV)

Andrei-Mihai LUCHIAN[*] Mircea BOȘCOIANU[**]

[*]Transilvania University, Braşov, Romania
[**]Air Force Academy, Brașov, Romania

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Abstract: *This paper main objective is the use of multi-agent systems to model micro-unmanned aerial vehicles (MAVs) for a distributed control load. We used a search scenario in the context of urban security and counter-terrorism. Using a simulation for autonomous MAVs, controlled by a neural network, the MAV must approach a target placed somewhere in the given environment and then detonate near it. First, we provide an overview of the latest generation of distributed control and communication in multi-agent systems. Afterword, the unmanned flight field from a historical perspective. Finally, we review the most relevant work on autonomous motorway planning. In the second part of the paper, we describe a simulation that includes a description of the developed MAV swirl simulator software. The results of the first set of simulations are general. The most appropriate set of sensors for neural network inputs, the evolved population of MAV swarms is capable of reaching and destroying the target on average 93% of the time.*

Keywords: *MAV, neuronal networks.*

1. INTRODUCTION

Distributed control is an interesting issue, hence from its technological and scientific view due to the synchronous movements that are necessary for coordination. In comparison with centralized control when an operator or leader establishes the plan and details the autonomous systems can easily resolve the issue and act immediately for the mission's success. Such systems require a partial interaction with other agents and small and simple data which are distributed around the world. These types of systems have a significant advantage due to the fact that they adapt instantly, without any mistakes, there is no time to waste for an answer from an operator, thus the speed of reaction increases dramatically, and there is no re-planification needed.

Adaptive solutions can appear anytime through the interaction between autonomous systems and the intelligence request which is not fully know at the beginning of the mission.

Studies regarding distributed control usually use Multi-Agent Systems (MAS) because it can simulate and test different platforms based on artificial intelligence. [1]

The MAS methods have been in used in wide area of domains such as UAV (unmanned aerial vehicles), terrestrial vehicles, search and save, social knowledge, etc. Some researches such as Sastry and others concentrated on subaquatic systems (Eklud, [2]); Sykara (Koes, [3]) concentrated on hybrid systems for search and rescue based on humans, software's and autonomous robots. What I propose is the use of coordination architecture capable of finding fast solutions for all the issues that appear, planification for mission regroup and if the system is restrained due to multiple threats.

In the project SWARM-BOT, Baldassarre [4], the group of robots Trianni and Dorigo [5] develop a common cooperation strategy for exploration. The distributed coordination control is not managed by one operator or a leader, it is the result of auto-organization, for example positive feedback. Eventually, there have been proposed a diversity of MAS models such as those which study the behavior with animals, ant colonies and the predator group behavior.

An important issue that was not studied directly in the distributed control MAS is that of communication between agents and people in hybrid systems.

Most MAS models consider communication typically and they refer to implicit forms of communication. For example, visual clues in predatory models and communication in colonies. These communications can be of the most value in tasks that require higher-level cognitive capabilities: planning and decision-making, as well as the integration of cognitive and language skills.

New studies as explicit communication has many implants. First, agencies that are authorized to communicate explicitly during the execution of a collaborative task could benefit from the exchange of information on the characteristics of the task being processed.

Thus, explicit communication systems cannot be defined by the humans but can emerge from the social interaction between agents. Another advantage of studying symbolic communication concerns the development of human killing systems and a human / robot / human hybrid system.

Finally, post-hoc analysis of the communications systems developed by agents can provide a meaningful insight into the best strategies. This can also be used to design and improve control systems distributed to humans.

2. UNMANNED AERIAL VEHICLE (UAV): GENERAL PRESENTATION

First of all, it is crucial to define the description of unmanned aerial vehicle, also known as a UAV. To do so, we will adopt the definition provided by the Military and Associated Military and Associated Dictionaries Dictionary [W1], which states: „A powered vehicle that does not carry a human operator, uses aerodynamic forces to secure the lifting of the vehicle, it can fly autonomously or can be remotely piloted, extendable or recoverable and carry a lethal or non-lethal task. Semi ballistic, cruise missiles and artillery missiles are not considered unmanned aerial vehicles".

An advantage for using UAVs instead of traditional crewed aircraft are to avoid human loss and, in the same time, increase the chances of success for their missions. In fact, as Cambon and colleagues [W2] report, unmanned aerial vehicles are commonly used in so-called "dull, dirty and dangerous" missions. The "boring factor" is easy to understand: during long and repetitive missions a car could offer a better alert status compared to a person, improving the overall success probability for the mission.

The "dirty" aspect is related to the tasks where the danger comes not from the enemy, but from another source. For instance, despite the fact that they wore lead-fitting suits and the plane was shattered at landing, American pilots who flew data collection missions on the Pacific Bikini Atoll immediately after the 1946 nuclear tests suffered a radiation illness. Ultimately, the "dangerous" factor could be both physical and political.

Physical, if we consider that a crewed aircraft exposes pilots to any kind of risk, especially during reconnaissance missions. Political, if we consider the issues of capturing a person. Some sources, for example, link the American built unmanned aerial vehicles with the U-2 spy plane shot while flying over the Soviet Union sky during May 1960 and the subsequent capture of its pilot, Francis Gary Powers, by the Russians.

Driving the so-called "U-2 crisis," this event clearly demonstrated to US governors how it was not politically acceptable to capture a pilot by the enemy during the Cold War.

In recent years, due to the rapid improvements in technology, a new category of UAV has emerged. These are called micro-unmanned aerial vehicles (MAVs), properly known as Class I UAVs, as defined by the US Army [W3], which states:

The Unmanned Aerial Vehicle of Class I (UAV) offers the soldier dismantled with the Recognition, Surveillance and Acquisition Target (RSTA). Estimated weight is less than 41 pounds, the air vehicle operates in complex urban and woodland land controlled by dismantled soldiers. The aircraft can also be equipped with EO / IR / LD / LRF capacity to carry out the RSTA mission and use a heavy fuel engine (HFE) as a propulsion system.

Class I uses flight and autonomous navigation but will interact with the operator’s network to dynamically update the targeted routes and information. Sometimes it provides assistance for early recognition and warning. It will also realize a limited relay to communicate in limited field action. The system (which includes an air carrier, control device and ground support equipment) is packed in the rear.

The MAS category is, in fact, only the natural result of the evolution of the UAV that have taken place over the last decades. They, became smaller and lighter than their predecessors, reaching true points of excellence. Consider, for example, the MC2 EPFL, a 5-gram fixed wing aircraft made of carbon fibers and thin films Mylar [6] [7] or MicroGlider developed by Wood and colleagues [8].

Even if we are now faced with a race to the most extreme forms of miniaturization, we already have reached a point where MAS can be successfully applied to innovative tasks. [9]

3. AUTONOMOUS PLANNING OF UAV / MAVS

The fact that an aircraft is not capable of transporting human pilots directly implies that it must be conducted in a different way. Nowadays,the UAVs that are currently used in real application scenarios are being controlleddynamically from a distance by a human crew that is in a remote position using a Tactical Control Station (TCS). Using multiple UAVs, at the same time, means that they must have their own guidance systems.These guidance systems are slightly similar to autopilot used in civil aviation, as they simply provide the UAV with a certain plannedroute.

Focusing on autonomous guidance systems is not just an economic issue, even if the use of robots flying instead of the usual "crew plane plus the human pilot" would save the enormous amount of money needed to prepare pilots. The idea is that a computer program can usually exceed a man in carrying out many different tasks, both in terms of reliability and accuracy.

The issue currently stated is that a human pilot is limited when we think of driving a bunch of MAS in city environment. To be capable of controlling various members of the party from a remote position means to be able to manage an infinite flow of information that enters the TCS every second and to answer properly. The flow of information is incomparably higher than that usually received by a pilot driving a Predator several kilometers above sea level. It is virtually impossible for a man to manage all this data that comes from the field. This is actually impossible if we want to hire dozens of MAS and move them like a real swarm. This is the main reason for increasing the interest in autonomous robotics.

According to Richards and colleagues [10], the current approaches to autonomous control of UAV cooperation can be divided into several different groups:

• deliberative approach: focused on developing a specific flight path for each UAV to follow. Such flight paths are rigid and no effort is made to modify them if new information is received (such as the discovery of a hostile element in a war environment).

• the adaptable replanning approach: To achieve certain degrees of flexibility, some deliberative systems include an adaptive re-planning element. In adaptive replanning, a centralized controller generates a specific flight path for each UAV to follow based on currently available information. The UAV follows that flight path by sending sensor information back to the controller as it becomes available. As the controller receives new information, it can generate new flight paths that are transmitted back to the UAVs. New plans may, for example, consider locating an unknown previously unknown enemy or that a UAV was lost due to a mechanical failure or for many other reasons.

• Reactive strategies: rather than generating a specific flight path that needs to be updated during missions, this approach tends to generate a so-called "reactive strategy" for each UAV.

In the aforementioned paper by Richards et al., Where a UAV team has to cooperatively explore a particular area, the decision tree that controls the various aircraft is developed through genetic programming methodologies. Even if the main idea - according to the controller system cannot be something outside the UAVs but needs to be incorporated - could be fully agreed, a more convenient approach could be to use evolving evolutionary neural networks (Parisi et al., Noli and Parisi, Floreano and Mattiussi, Mitchell), mainly for two reasons. First, it's easier to use neural networks instead of GPs for this type of task, because the behavioral deposit you give to MAVs is much simpler. Second, if properly trained, neural networks allow a much larger generalization capacity than a decision tree that evolved through genetic programming.

However, in both cases, a computer simulation is needed for cost and time reasons (for an overview of the importance of simulations in modern science, see Casti [11], Parisi [12], Cecconi and Zappacosta [13]). Developed strategies need to be evaluated in the simulated environment because the evolutionary process potentially requires thousands of evaluations of the strategy to converge on effective solutions.

Neural networks are commonly used in terrestrial and underwater robotics, but very rarely as control systems for flying robots. The main exception to date, the review of literature, is the work that Floreano and colleagues [14] [15] carry out at EPFL. Their project is focused on hiring fully autonomous MAVs where each member of the roi acts as a signal repeater to create a secure communication infrastructure between human rescuers and the base station working in areas affected by natural disasters. At the same time, Owen Holland and his research group [16] [17] are studying how to use neural networks as controllers for autonomous helicopters.

Finally, even if this approach falls within the adapted re-planning category, other significant insights come from the work carried out within the Autonomous Flight Systems Laboratory at the University of Washington. Emphasizing the importance of using heterogeneous autonomous systems instead of traditional hierarchical structures, Rathbun and Capozzi [18] have developed an efficient route planning algorithm for situations where UAVs have to modify their paths to avoid a range of other flying aircraft near.

4. CONCLUSSIONS

In this paper we have showed how a neural network controller for MAVs can be successfully developed using a computer simulation based on evolutionary algorithms.

With a more realistic environment, we could add to the MAV's behavior a social dimension. Thus, replacing the target with a more robust one that needs two contemporary hits to be destroyed.

Another direction would be to increase the number of MAV members belonging to a swarm and vary the starting points. This way, we will be able to develop a true swarm behavior. After we can suggest the use of non-cloned MAVs, individual characteristics (such as would be, for example, a preferred direction to be followed when approaching prey).

Gradually, the aim is to move on to a more realistic scenario. We will use a three-dimensional environment that contains objects characterized by real physical properties.

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