Evolutionary Cloud for Cooperative UAV Coordination

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1 The domain

This report is about UAV (or drones), cloud computing and smart cities. An UAV is an unmanned aerial vehicle piloted by remote control or onboard computers. Cloud computing can be described as the practice of using a network of remote servers hosted on the Internet to store, manage and process data. A smart city is an urban area that uses sensors in order to supply information used to manage assets and resources efficiently. In the report, it is said that a smart city is "a large multilevel construction where the buildings, streets, shops, bridges, traffic lights and so on, can discuss, collaborate, make decisions,and perform actions with or without human intervention".

2 The subject

The idea is to link the three components introduced in the first part (I - The Domain) in order to assist human actions in emergency situations. It means that the UAVs will have to act in unpredictable situations and with incomplete information. Throughout the report, there is the example of a forest fire which becomes a secondary problem when heavy rains start a flood.

The aerial aspect of UAVs gives them unmatched mobility and speed which is necessary in emergency situations. Those ones need a system that can collect, process and provide all the data that are necessary to determine the actions to do and their priority in real time. Smart cities can collect and provide these data, while cloud computing enables to treat a big amount of information (big data).

3 State of the art

Earlier, the objects used in such situations were static and only gained a few capabilities thanks to a sort of consciousness. Now, there has been some studies where vehicles could move but there wasn't any cooperation between them (for example Gonzalez et al. in 2009). Smart cities are starting to be developed but installing sensors everywhere in a city is still too expensive. Therefore, they are not very numerous and they don't have an important impact in supplying data about the city's environment. Moreover, there are no links yet between UAVs, smart cities and the cloud.

4 Scientific content abstract

The idea of this report is to use UAVs because of their mobility and to make them collaborate in order to use them during emergency situations. Those would have access to a big amount of live data and information about past operations thanks to smart cities and cloud computing.

In the next section, we are going to give a description of the problem treated. Next, we will see why it is an optimization problem. Then, we will discuss the usefulness of cloud computing in these situations. After that, we will explain the use of semantic agents to help UAVs perform their missions. Finally, we will detail why this is a big data problem.

5 Scientific content

Emergency situations evolve in unpredictable manners. Therefore, there is a need for real-time optimization and coordination of autonomous UAVs. There has not been any dynamic cooperation between UAVs in the past, anyway it is acknowledged that there is also a need for automatic generation, execution and partial verification of mission plans. In the report, the authors add that validation of the plan is also necessary.

Moreover, UAVs must work on their own while cooperating with one another. This way, if a UAV is broken, it does not prevent the others from accomplishing their tasks. If it loses communication with the others, it must continue to do its mission. That is the reason why it has to be a hierarchical model able to change considering the situation.

UAVs don't have enough on-board processing power to collect and process all the data they need for their missions. Thus, the idea is to use cloud computing beside it, for example to filter out the most interesting information, because it can provide adaptive computational power and storage capacity while improving fault and failure tolerance thanks to the replication of large sets of data and distribution of work load. However, it is said that the latency of Cloud Computing for certain tasks is proof of a need for an adaptive hybrid solution with Cloud Computing and real-time systems on board.

The system primary goal is to keep itself in an ideal configuration. However, a lot of factors such as the environment, the devices and the state of the mobile network can influence the overall performance. Finding an optimal configuration every time is impossible to perform, and requires reasoning using the open world assumption.

One aspect which can be optimized is the flying routes of UAVs. The best outcome is not necessarily the less time-consuming route because of dangers in some areas. So, it can be reduced to finding a minimum of a given cost function for the mission which is too complex and expensive to solve analytically. The use of some form of evolutionary computing is promising because the function would be considered a black-box. Computing values from the function would then be enough and most algorithms can be highly parallelized.

The communication environment can also be optimized so that the network remains reachable. It is needed and possible to save power and lower interferences by planning as much as possible before the mission. Furthermore, it might be useful for drones to move in order to have a better connexion and thus save time on the data transfer.

Amidst grid and cluster, Cloud Computing has been chosen because it provides rapid scalability, high security and privacy, and strong support for fail-over and content replication. It is thus expected that the services in the infrastructure assist the overall system by coordinating and configuring the other components. It is said that both great amounts of storage capacity and computing power are needed in order to cope with disasters.

Three different strategies could be implemented for the problem. The first one is the centralized strategy. The idea is that there is one central component that controls all the system. It seems a good strategy in our case, where Cloud computing would be the central component. The problem is that, with this method, the latency in communication can be extremely high. Moreover, this strategy is a single-point-of-failure. It means that if the central component doesn't work anymore, the whole system won't be able to work.

The second strategy is the distributed strategy. It seems good because each robot has some information stored locally that allows it to work by itself. The main problem is that the mission time can be very important, due to the fact that the robots can't perfectly perform their missions only with the data stored locally.

The third strategy is the market-based approach. The idea is that a central component chooses which robot will perform the task by comparing the resource usage. With this strategy, the mission time is between the centralized and the distributed strategy.

In our case, the good idea is to use a hybrid of the distributed and the centralized strategy, close to the market-based approach. This way, Cloud computing would be associated with real-time systems on board in order to ensure an optimum render. However, no matter the solution, humans have to be in the equation, for example to solve tasks that would not be computable within reasonable time, or, for our example of a fire, to rescue people.

Entities in Smart Cities are smart resources, that is to say entities with some kind of identity and relations with other entities. Agents are the representation of a smart resource. They encapsulate them in order to give them the ability to communicate with one another. Semantic Web is the idea that real world entities and their relations can be seen as web documents and their links. Its use seems to be a natural concept to describe and exchange information. Moreover, the unexpected nature of disasters implies the use of the Open World assumption. This means that if we don't know something about an entity, then we do not assume that it isn't true. Instead, we assume that our data is incomplete.

A multi-agent system performs better than a static system if faced with dynamics scenes. Agents autonomously implement strategies. It allows Mobile Agents to distribute new strategies while the system is running. The fact of using both agents and the Cloud allows the use of the Cloud's computational power. The UAVs could decide to disable some of their sensors to save energy by using each other's data. Moreover, it is not a problem if one UAV is down, because its mobile agents can move so that another UAV can perform its tasks.

Our situation with UAVs, Smart Cities and Cloud computing can be seen as a big semantic data problem. Indeed, the problem has three aspects : the idea is to work with a large amount of data that varies over time with a high velocity.

The system can be evaluated on its efficiency, which is the ratio of the utility to its effort. That means to show the usefulness of the extracted data when compared to the time and resources used to perform this extraction. The more efficient the system, the more computational the complexity. If the complexity rises there will be a risk that the system's efficiency drops.

Moreover, the system will have to extract an unmanageable amount of knowledge. This means that an approach must be identified. There comes the 3F+3C approach, which stands for Focusing, Filtering and Forgetting + Contextualizing, Compressing and Connecting :

- Focusing: the scope of the focus in order to have the best efficiency
- Filtering: filtering the most important and useful data at the time
- Forgetting: trashing useless information
- Contextualizing: the data's context (tools used, place,...)
- Compressing: lossy compression (Forgetting) and lossless compression (repetitive patterns)

- Connecting: linking data before precessing it

Furthermore, using an evolving knowledge ecosystem could counteract the unpredictable nature of disasters. This system would keep the fittest knowledge for its environment while removing everything else. The benefit of this system would be its evolving nature over time. It can thus adapt itself to new trends in the data. Moreover, it is able to send signals to the outside world in order to gather specific data. It would thus be able to recognize patterns and act in accordance.

6 Objectivity about the report

The report contains many ideas which are probably achievable. Moreover, there are many references and an example with a forest fire. However, nothing is really "concrete": there is no code, no algorithm, or no mathematical formulas. Everything is abstract.

The authors know the direction of their future research. It will be in a theoretical perspective while adding more experimental perspective such as studying what kind of robot is the most useful in which environment for example.

7 Conclusion

Smart Cities are required in order to provide data to the UAVs. Moreover, the system overall performance can be improved by the use of a collaborative fleet of UAVs. Furthermore, a multi-objective function must be continuously evaluated in order to keep the system in an optimal state and the use of evolutionary computing is thus proposed. The system will need an unimaginable amount of computing resources which is why Cloud Computing was selected in this report. It is also stated that the fleet of UAVs also needs to work autonomously and that mobile agents are a must in order to integrate and analyse data. Moreover, there is a Big Semantic Data Problem because of the data's velocity, volume and structure. This is why an Evolving Knowledge Ecosystem is proposed to integrate information from different sources.

8 Bibliography

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