Summary: Task Assignment Problem for UAVs

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The summary contains the multiple UAV hierarchical and distributed coordination and control research problem which is a part of MASC Project. The problem is formulated from the following concept:

A shared pool of UAVs autonomously providing service on-demand. Namely, a network of UAVs loitering above the area of operations will provide services to multiple users as they "dial up" directly to the network to request for services at various times. Algorithm are required to run onboard the UAVs to keep the network coverage over the area of operations and allocate the best-suited UAVs to provide the requested service, all without the intervention of a ground component. This removes the need for a ground component to be continuously managing the UAV operations. The research problem of dynamic tasking are actually derived from this concept. The benefit of such kind of approach are obvious, for example in current UAV operations, the UAVs are centrally managed and user requiring UAV services would have to make a request to the centralized agency controlling the UAVs. In opposite to proposed here the new concept that allows the users to bypass the centralized agency to request for services. In this concept, the UAVs manage themselves automatically as a team in a hierarchical and / or distributed manner. The pool of UAVs would loiter above the area of operations and await service requests. Upon receiving a request, the best-suited UAV is deployed to provide the service to the user. At the end of serving the request, the UAV would return to the pool to serve another request. The centralized agency is no longer involved in receiving requests and allocating UAVs to the requests. It only needs to ensure that there are sufficient UAVs in the pool to service the requests. The research on Dynamic Tasking are address the problems of a hierarchical and / or distributed approach to provide automatic self-allocation and self-deployment to support this new concept.

To realize this concept, there are three groups of UAVs within the UAV team, each performing a different role. The operations will be confined to some specified airspace which is termed the UAV Airspace . The three different groups of UAVs are:

- Tethered UAVs. These are responsible for providing communication links between the ground users and the UAV team. A Tethered UAV will loiter in the region above its associated users to maintain a communication link with them. As such, each Tethered UAV is, in a sense, virtually "tethered" to its associated set of ground users. One of the ground users will be designated as the primary ground user. When there are more sets of ground users than Tethered UAVs, the primary ground user should always have a Tethered UAV above it.
- Service UAVs. These are responsible for responding to service requests from the ground users.
- Air-net UAVs. These are responsible for providing communication coverage in the UAV Airspace which is where the Tethered and Service UAVs are expected to operate in. In this way, all the UAVs and the ground users are networked with each other at all times.

The logic for that problem is hierarchical and / or distributed in general.

Remark 1. *The Different Control Structures*

- *Centralized control means that all the decision making and control are performed by one entity in the system and the decisions and control actions are disseminated to all the subsystems for execution.*

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- *Decentralized (or hierarchical) control means that a system level controller is divided into several pieces, such that each subsystem takes one set of tasks. It is also said to be hierarchical and could achieve the similar performance of a single system level controller (centralized). The system may fail to run if one subsystem has a fault. It is different from a centralized system as each subsystem has some decision making and control authority given to it.*
- *Distributed control refers to the case where each subsystem has its own intelligence and all are peers without primary-slave relation. Hence, even when one or some subsystems fail, the overall system can still perform the designed task possibly with performance degradation.*

Particulary in D6 report we have shown that dynamical assignment problem for allocation of MAS in frame of the above logic can be presented as a static integer programming problem where the challenge is to maximize the number of service requests that can be serviced. But this way leads to the huge dimensions of the variables involved, and this together with the specific structure of the considered problem are a serious obstacle for suitable solution for reasonable time. By this reason we present the special new adaptive method for such kind of assignment problems of MAS. And the main benefits of the proposed approach are:

New optimality and sub-optimality conditions that are more suitable for the design of the quick numerical methods and further applications;

Adaptive. The UAVs can redeploy themselves when the inputs are changed

Low on overheads. Consideration should be made to minimize the communications and computation required.

Robust. The logic are still work when any UAV fails, when communications are lost intermittently or when the UAVs are displaced from their intended trajectories by normal uncertainties and disturbances.

In the next D7-D8 report we are planning to extend the proposed logic for more specific scenario, which will include the following parameters:

- Tactical-class UAVs
  - 3 Air-net UAVs
  - 3 Tethered UAVs
  - 6 Service UAVs
- Speeds: 30 - 80 m/s o Speeds: 30 - 80 m/s
- Climb rates: 2-5 m/s
- Max bank angles: up to 60 deg
- Turn radius: 200 - 600m
- GPS/INS navigation accuracy: 10m
- Endurance: 1 - 12 hrs
- Air-to-air communications range: 1-5 km
- Area of Operations: 20 x 20 km

The end goal of our investigation is to realize the proposed hierarchical(decentralized) and / or distributed logic that will enable the UAV team to assign the new tasks to the best-suited UAVs in order to achieve good overall task servicing performance. The simulation model for two dimensional case will be created on AnyLogic simulation software using the agent-based modeling approach, since it allows creating flexible models with agents, interacting with each other and their environment. AnyLogic supports all known ways of specifying the agent behavior statecharts, synchronous and asynchronous event scheduling.