A MISSION COORDINATOR APPROACH FOR A FLEET OF UAVS IN URBAN SCENARIOS

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Smart cities will provide services to the community for huge different applications and will improve:
FLEET OF DRONES

- Ability to cover different missions in terms of time and covered distance
- Payload characteristics and flexibility
- New approach in urban scenarios
- Optimize time, consumption or other factors
- Heterogeneous vehicles
STATE OF THE ART

- UTM
- Mission coordinator
- Path planning
- On-Board Control
CLOUD-BASED APPROACH

Advantages:
• High computational performance
• Path planning
• Optimal control techniques
• Data storage

Disadvantages:
• Rely on a network coverage (5G)
• Robust strategy in case of disconnection
OBJECTIVES

• Standardization of the use of a fleet of heterogeneous vehicles in urban environment
• Minimum risk level for the population
• Optimization of autonomous strategies
• Vehicle coordination in cooperative missions
• Human operation avoidance

NOVELTIES

• Development of an autonomous urban mission coordinator through a functional cost to complete complex mission with a limited number of operators.
• A centralized control is proposed
• Implementation of an algorithm based on a tree optimization method
VEHICLE CONFIGURATIONS

- Fixed wing

**Advantages:** high speed and operative altitude, good endurance and range performance.

**Disadvantages:** take-off and landing maneuver.

- Rotary wing

**Advantages:** flexibility, hover capabilities, take-off and landing maneuver.

**Disadvantages:** endurance and range performance.
MISSION CLASSIFICATION

• **Monitoring missions**: continuous scanning of a defined area, suitable in case of environment management or industry purposes.

• **Inspection missions**: assessment of area to evaluate its current state to reduce risk in hazardous environments, cost and maintenance.

• **Delivery missions**: mean collect, transport and deliver goods from a starting to a final point, reducing traffic on city roads, air pollution as well as last-mile cost.

• **Intervention missions**: interaction with objects or people to improve or support their state, improving the capacity, speed and quality of existing services.
TWO CATEGORIES

**Delivery missions**
in which the vehicles should reach a target destination to perform specific actions.

**Coverage missions**
in which the vehicles should be able to scan a confined area or take multiple snapshots inside a limited space.
MISSION DEFINITION

• UAV’s positions are $\mathbf{x}_i(t)$ with $i = 1,\ldots,n$.

• Docking station’s positions are $\mathbf{x}_{dk,j}(t)$ with $j = 1,\ldots,m$.

Coverage and delivery applications are responsible for complementary mission constraints.
ARCHITECTURE

- Unmanned Aerial Vehicles
- Ground Vehicles docking stations
- Cloud System

5G mobile network allows safe mission execution and accomplish.

A mission coordinator approach for a fleet of UAVs in urban scenarios
MISSION COORDINATOR REQUIREMENTS

- **Mission demand**: defines area, objectives, restriction and time.
- **Vehicle dynamics**: each vehicles defines different dynamics.
- **Vehicle resources**: take into account for example a battery level.
- **Traffic management**: a cooperative missions is required.
ARCHITECTURE

Mission coordinator sends a path planner to single drone.

- **Offline path planner**: all possible trajectories to accomplish the mission are computed and stored.
- **Optimization system**: selects the optimal solution, taking into account all single trajectories

An **Online path planner** manages the vehicle trajectories when unpredicted obstacles are detected.
TREE STRUCTURE

Each mission could be performed by one or multiple vehicles and be divided into different task.

A tree structure is a technique to accomplish the task in an optimal way.

- **Nodes** represent a vehicle changes, docking station or final point.
- **Edges** represent a specific trajectory of a drone with their cost.
- **Branches** include all edges to comply mission constraints.

\[
J = \sum_{j=1}^{i} c_j b_j
\]

where \(b = [b_1, \cdots, b_i]^T\) is the weight vector optimization and \(c = [c_1, \cdots, c_i]^T\) is the vector to be optimized.
**EXAMPLE: a delivery mission**

In this scenario has:

- four available docking stations
- two available vehicles
- a start cargo point
- a target point

1. \(v_1\) or \(v_2\) could pick-up cargo in start cargo point without a offline trajectories.

2. There are 5 possible trajectories or edge in the tree, from start cargo point to the 4 docking station and target point.
EXAMPLE: a delivery mission
SIMULATION: a delivery mission

The task of the mission is to transport the cargo from the pick-up point to the target point with two docking stations available.

Vehicle dynamics have been simplified by adopting a polynomial model.
SIMULATION RESULTS

We obtained the optimal trajectories, choosing the branch with minimum cost. The thickest branch is the optimal one and indicate selected tasks.

The solution expects that vehicle one picks up the cargo, arrives in the docking station 2 where a cargo transfer occurs and finally, vehicle 2 reaches the target.
CONCLUSIONS

• A coherent high-level methodology for the autonomous coordination of a fleet of UAVs in an urban scenario has been presented
• A Mission coordinator and a tree structure have been proposed
• A Cloud-based approach permits to reduce drastically computational effort
• A simple simulation example was presented to explain the method feasibility

FUTURE WORKS

• Integration with a path planning algorithm more realistic to replace polynomial function
• Software-in-the-loop analysis
• Test with real vehicles
THANK YOU
FOR YOUR ATTENTION

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