Functionnal Modules for Intermixed Planning and Execution of an Observation Mission

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1 Introduction

Mission management of an autonomous vehicle in an unknown, dynamic environment is a complex real-time problem. The use of distributed hierarchical system architecture [2] or compositional methods [3] represents a way to reduce the system complexity. That hierarchical structure is widespread but precise implementation has not yet been described in the literature.

This paper presents the implementation of functionnal modules developed for intermixed planning and execution of an observation mission of an Unmanned Air Vehicle (UAV): the mission and its characteristics are detailed in section 2; the execution control structure is briefly described in section 3; the behavior of the UAV is specified in hierarchical Petri nets (section 4); embedded computational sub-systems are defined in section 5; section 6 presents numerical experiments by simulation with scenarios and results.

2 UAV Mission

The implemented mission is a mean altitude navigation from an initial position to a final position in a partially known 3D environment. The mission may optionaly include generic operations to be performed at some mission points:

- mission points with operation: area survey, outline following static object search and waiting on hippodrome;
- other mission points: ascent, descent and allied border crossing.

Constraints are induced by the vehicle itself, the environment (such as forbidden areas) and the mission (operations to achieve). Planning aims at minimizing path length and fuel consumption and satisfying date constraints. Uncertainties are related to path following and operation execution. On-board replanner capabilities are so required to take into account these uncertainties.

3 Execution Control

The ProCoSA [1] execution control tool is an environment developed for implementing advanced mission management in autonomous vehicles. The software includes a graphic user interface for off-line mission preparation : the desired behavior of the UAV is specified with Petri nets. The global system can include computational sub-systems which are executable tasks. An automate called the Petri player runs the system in accordance with Petri nets; it communicates with the sub-systems by receiving events and sending requests. The communication protocol is based on sockets.

4 Petri Nets

The observation mission and the operations are implemented on ProCoSA by using a distributed hierarchical system architecture.
A Petri net (Figure 1) at the highest level specifies the high level execution of the mission. One activated place in this MISSION Petri net represents the phase in which the UAV is.
Mission phases are then described in several generic and hierarchical Petri nets. MISSION calls successively six nets:

- PLANNING (itinerary and trajectory planning),
- TAKE-OFF,
- MISSION PREPARATION at the beginning of the mission,
- NAVIGATION TO MISSION POINT, to navigate to the next mission point,
- OPERATION, which calls a Petri net for each specific operation,
- LANDING at the end of the mission.

Local on-line planning (trajectory level) is performed if the current trajectory is no more consistent with its prediction. If local planning fails, the global on-line

planning at itinerary level is performed. On-line planning takes also into account unpredicted events: not enough fuel, operation failure...

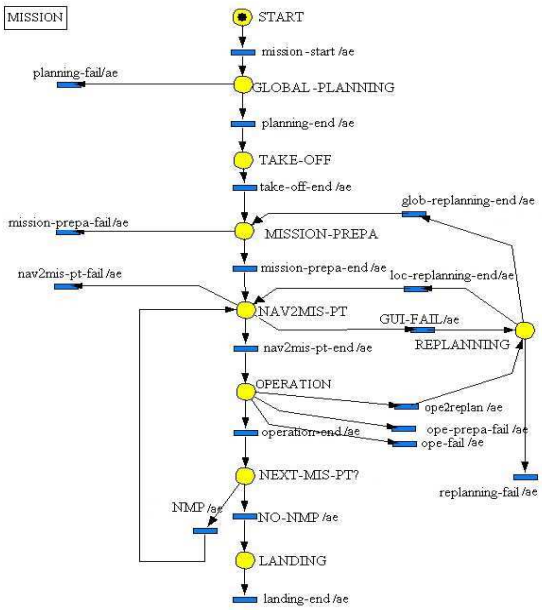

Figure 1: MISSION Petri net

5 Sub-Systems

The main sub-system is the planning algorithm which optimizes the sequence of mission points (itinerary) and the trajectory from each point to the next point taking into account constraints due to the vehicle, the environment and the mission. Another sub-system computes the guidance controls sent to the UAV (commanded speed, next waypoint, commanded heading) taking into account flight dynamic characteristics of the vehicle. One sub-system centralizes all required information in order to simplify communications within the on-board architecture. These sub-systems are implemented in C language.

6 Numerical Experiment

An observation mission using all types of mission points has been simulated on a 220km$\times$160km area. The trajectory and the itinerary of the UAV are recorded in order to verify the guidance controls. The mission lasts about 25 hours.

The objectives of simulations are to highlight the on-line replanning capabilities on the proposed architecture and thus the efficiency of intermixed planning and execution architecture for an UAV. In a first simulation, the planning algorithm is tested in a normal situation. The optimal path is computed by the planning subsystem and all operations are correctly executed.
A second simulation aims at testing the replanning architecture. A failure event is sent to the system and adequate on-line replanning is performed.
The architecture using ProCoSA tool is thus validated in a nominal situation and in a degraded one.

7 Conclusion

This paper has proposed a hierarchical on-board architecture for the execution of an autonomous mission by an aerial vehicle. UAV mission and operations are specified with ProCoSA by using distributed and hierarchical Petri nets. The Petri net at the highest level specifies the execution of the different phases of the mission. Sub-systems compute the planning and the guidance. Communications are centralized. Simulations highlight the efficiency of intermixed planning and execution for the on-line control of an observation mission of an UAV.

References

[1] « http://www.cert.fr/dcsd/cd/PROCOSA ».

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[3] Bruno Sinopoli, Mario Micheli, Gianluca Donato, T.John Koo. « Vision Based Navigation for an Unmanned Aerial Vehicle ». *Proceedings of IEEE International Conference on Robotics and Automation*, 2001.