Multi-Agent System to Design Next Generation of Airborne Platform

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The Studied Airborne Platform

- Remotely Piloted Aircraft System (RPAS)
- Employed during critical military operations
  - Convoy protection, surveillance, rescue
- Used in complex environments
  - Highly dynamic
  - Up to 500 field objects[1]
  - Pop-up & high-velocity objects on the field
- Complex to be controlled and managed through the Mission Manager (MM)
- A large set of instruments (including sensors) is required to achieve missions in real-time

The Dassault "nEUROn"

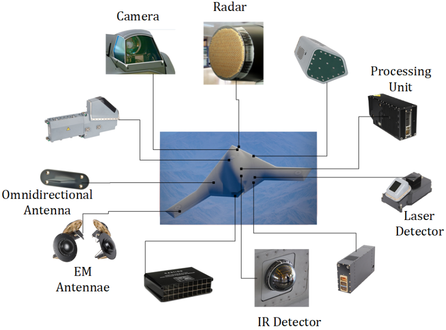
[1] Constituting the tactical situation or the "TacSit"

Sensors

Sensors...

- Are complex instruments
- Perceive the platform's environment
- Can be in conflict (*e.g.* 2 antennas for 1 frequency)
- Have limited processing capacity
- Provides multiple functions
- Work in different physical domains

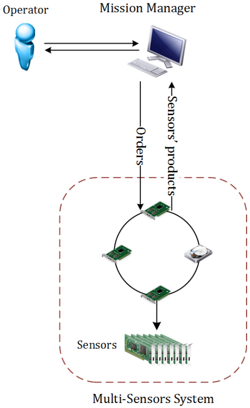
  > RF, Optics, IR, Laser, etc.



The embedded sensors

Abstract View of our Framework

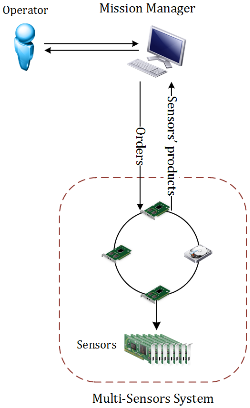
The Operator
The Mission Manager (MM)
The Multi-Sensors System (MSS)



Abstract View of our Framework

The Operator
The Mission Manager (MM)
The Multi-Sensors System (MSS)

- Propose essential functions for operations to the operator through the mission manager
  - Collect field data
  - Communicate
  - Navigate
  - Ensure the platform safety
- Enhance the sensors management
  - Improve the sensors' products
  - Coordinate the mission tasks
  - Balance the loads



MMS in the Next Generation Airborne Platform

Short term changes

- Increasing complexity
- Growth of functions number
- Constraints reinforcement
  - Hardware, threats, prices, size, etc.
- Expectations changes
  - Modularity, autonomy

Today's MSS limits

- Dedicated communications links
- Lack of sensors' cooperation and coordination
- Missing an unified sensors' architecture

Problem Settings

- Build efficient framework for the NGAP
- Overcome MSS limitations & short term evolutions

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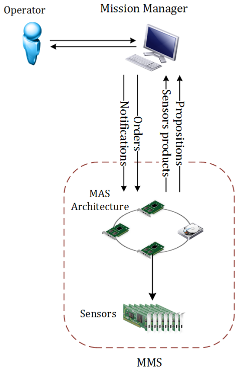
- Define new architecture with autonomy and modularity
- Enhance cooperation and coordination between sensors



Proposition

Define an agent-based architecture for Multi-Sensors Systems endowed with efficient sensors coordination

Proposition

Agent-Based Architecture for MSS

In the proposed architecture:

Agent → Field Object's **Digital Twin**

Each agent symbolizes one field object: "*Tactical Agent*".

In the proposed architecture

Agents: low-level & high-level roles

(Mission Manager ↔ Hardware Sensors)

Sensors Coordination

Fast & efficient scheduling algorithm

Working under high constraints & complex precedence scheme

Tactical Agent

Main Goal

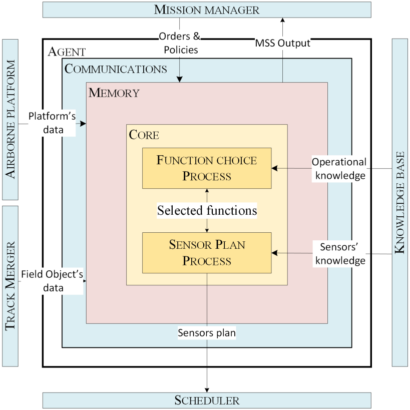
- Collect data of the embodied field object it represents

Three Roles

- Provide data to the MM
- Comply to the MM's orders
- Generate sensors plans

Required data by agents

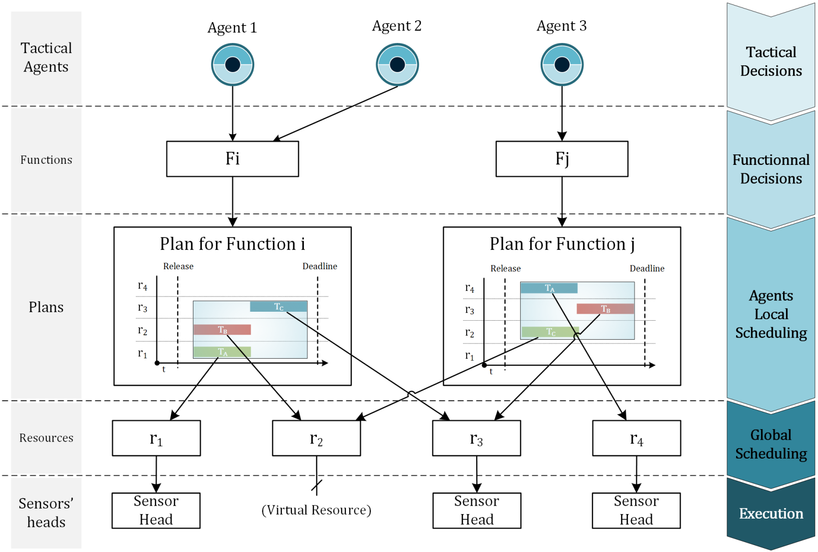
- Platform's data
- Orders & Policies (from MM)
- Sensors and Field Objects Data
- Operational and Sensors knowledge



The Tactical Agent

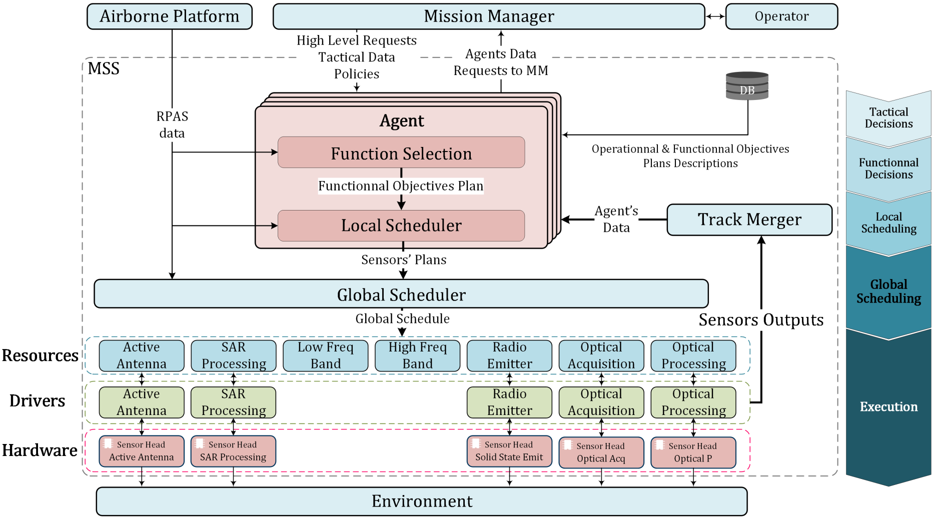
Tactical Agents are generic when created
They are instantiated according to new sensors data

From Agents to Sensors



The MSS agent-based architecture

Agent-Based Architecture For MSS



The MSS agent-based architecture

Agent-Based Architecture For MSS

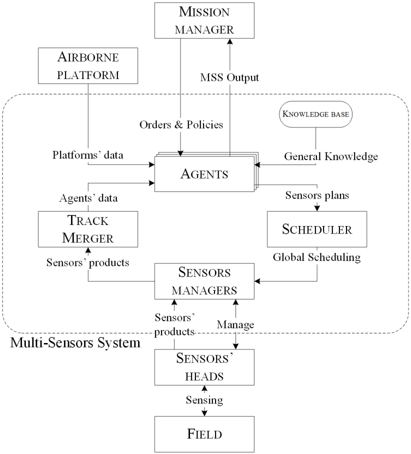
MAS bootstrap
Creation of the RPAS Agent

Tactical Agents (TA)
Interface *Mission Manager* ↔ *Sensors*

Track Merger Artifact

- Merges the sensors data
- Creates TA w.r.t. the observed objects in the theater
- Forward new data to the TA

Agents-Scheduler-Sensors-Merger
⥀ 4-Step sensors' control loop



A simpler view of the architecture

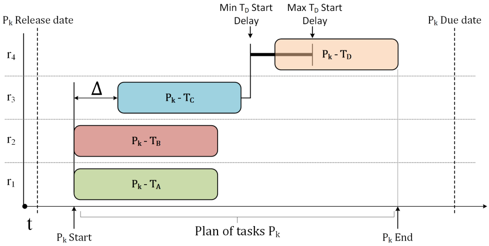
Coordination Based on Scheduling

K Plans of N tasks on R indivisible resources

- Complex General Precedences Relations
  - Start-Start, End-Start, Min/Max Start-Start Delay & Start-Start + exact Δ
- Plans precedences (*e.g.* P_i before P_j)
- Priority: $\Pi(Agent) = \Pi(Plans) = \Pi(Tasks)$
- Strict plans release & due dates, no delay allowed

Scheduling Criteria

- Minimize resources' free time
- Maximize scheduled plans priority



A strongly constrained plan of tasks

Scheduling Algorithm

Determines for each task its starting time (t_s)
Greedy fast algorithm, sweeps tasks and plans to find matching t_s

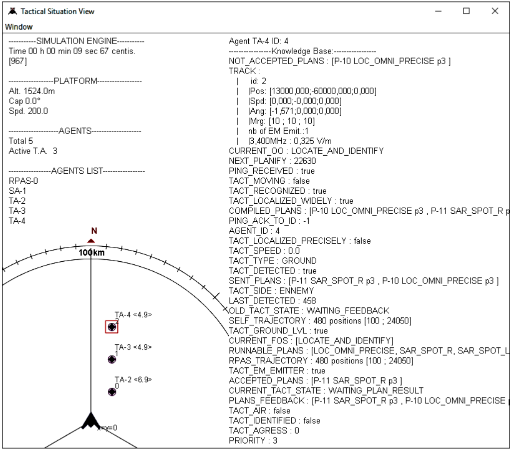
Sort the K plans by priority
↓
For each plan j
↓
For each task t
↓
Search compatible task's t_s
↓
If found, go to next task
↓
Else, shift t_s
↓
Else, shift the plan t_r
↓
If one task not scheduled
Abandon j

Input: $\mathcal{P}$ the ordered set of the whole plans of tasks
Output: t_s: the start time of each task T_n for each plan P_k
Data: T_H: Temporal horizon

$\mathcal{P} \longleftarrow$ sortPlansByPriority($\mathcal{P}$);
foreach *Plan Pk of* $\mathcal{P}$ **do**
- **while** $\exists T_n$ *unscheduled* $\in \mathcal{T}_k \wedge Pk.t_r < Pk.t_d$ **do**
  - **foreach** *Task Tn of* $\mathcal{T}_k$ **do**
    - $\mathrm{T}_n.\mathrm{t}_s \leftarrow$ precedence(C_n);
    - **while** $\neg$*isCompatible*(T_n) $\wedge T_n.t_s < T_H$ **do**
      - **if** *matchingConstraints*(T_n) **then**
        - nextTaskOfThePlan(Pk);
      - **else**
        - shift($\mathrm{T}_n.\mathrm{t}_s$); /* increment t_s */
    - **if** $\neg$*isCompatible*(T_n) **then**
      - shift(P$k.\mathrm{t}_r$); /* increment t_r */
- **if** $\exists T_n$ *unscheduled* $\in \mathcal{T}_k$ **then**
  - abandon(P_k);
  - adviseAgent("*unplanned*",ownersOf(P_k));
- **else**
  - addToGlobalSchedule(P_k);

Simulation

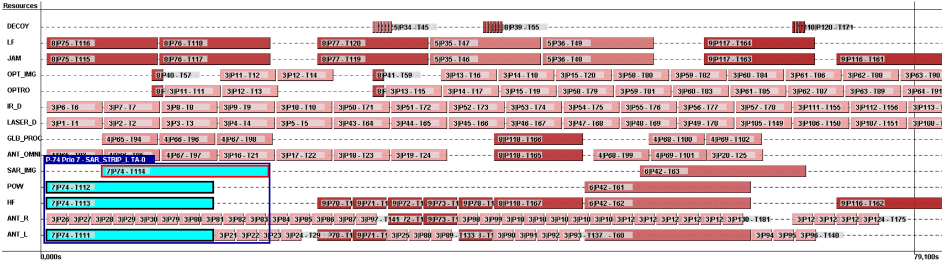
- Special Test Scenario
  - Operational Scenario
  - 10 usual tasks (e.g. localization, image capture by camera or radar, etc.)
- Developed in Java 1.7
- Simulation revealed
  - Improved MSS autonomy (orders are launched autonomously by agents)
  - Strong Modularity
  - Efficient Resources sharing
  - High field data granularity



Simulation's Main Frame →
Tactical situation, agents, knowledge base

Scheduling Simulation

- Fast scheduling: 88ms for 100 plans on a i7 processor
- Highest priority → first scheduled
- Satisfying integration in the MSS architecture



Example of output schedule

Conclusion

Piloted Platform

MAS for MSS
First breakthrough

First simulations
Requirements satisfaction

Upcoming researches
Multi-platform applications
Track merging solutions

Frigate

Thank you for your attention