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► To cite this version:

Mohand Hamadouche, Catherine Dezan, David Espes, Kalinka Regina Lucas Jaquie Castelo Branco. MoTie: Monitoring of mobile Things with Intelligent and embedded adaptations for secure services. Compas 2023: Conférence francophone d'informatique en Parallélisme, Architecture et Système, Jul 2023, Annecy, France. hal-04394631

HAL Id: hal-04394631

<https://hal.science/hal-04394631v1>

Submitted on 15 Jan 2024

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MoTie : Monitoring of mobile Things with Intelligent and embedded adaptations for secure services.

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Financed by : CDE / SAMM (ARED)

Term of the thesis : Oct. 2019 - 2023

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I. Context and problem statement

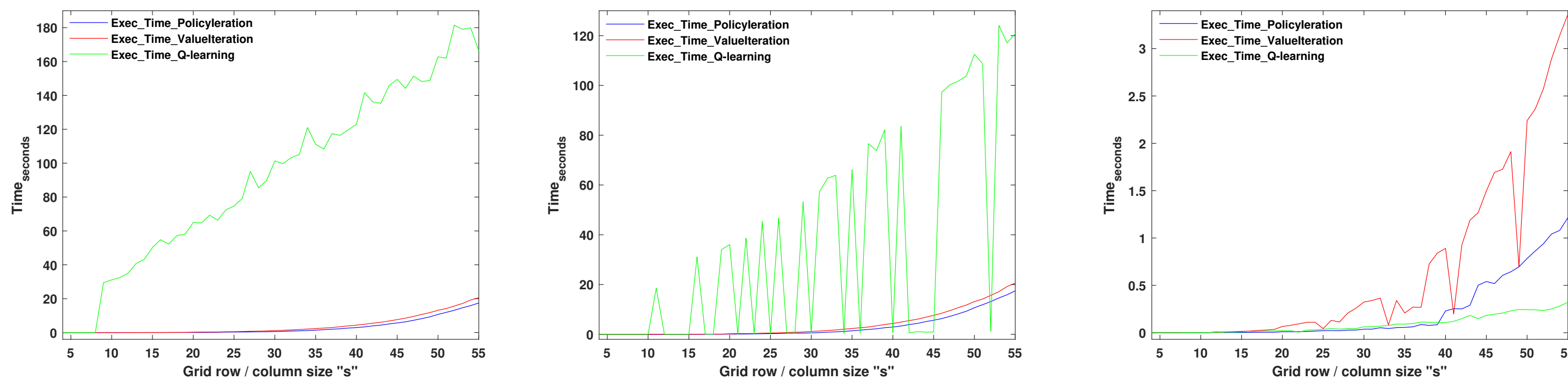
In the context of maritime mission,

- ❖ Cooperation with a UAV or Multi-UAV system improves mission quality, productivity, and safety.
- ❖ The UAVs provide a complementary viewpoint and the maritime drones are used as a 'Mothership'.
- ❖ Aerial drones have to face hazards (malfunctioning of the system/sensors, cyber-attacks e.g. spoofing).
- ❖ Many challenges in multi-UAV systems:
 - ➔ Distributed decision-making, taking into account conflicts;
 - ➔ Failures and safety threats in multi-UAV systems.



II. Comparison of fundamental methods for mission planning [1]

- ❖ Markov decision process (MDP) approach is the most common for modeling UAV missions.
- ❖ Fundamental methods for solving it:
 - ➔ **Value Iteration** and **Policy Iteration** which are Dynamic programming (DP) methods.
 - ➔ **Q-Learning** which is a temporal-difference (TD) method.



Execution time for size 4×4 to 55×55 : (a) Version 1-a. (b) Version 1-b. (c) Version 2.

TABLE III: Summary of 100 executions of the three methods of each version to solve the irregular grid.

100 Executions		Version 1-a			Version 1-b			Version 2		
		Value Iteration	Policy Iteration	Q-Learn.	Value Iteration	Policy Iteration	Q-Learn.	Value Iteration	Policy Iteration	Q-Learn.
Iterations	$Iter_{min}$	1,375	3	1,000,000	1,375	3	6	1,375	3	11
	$Iter_{max}$	1,375	3	1,000,000	1,375	3	1,000,000	1,375	3	1,000,000
	Average Iter	1,375	3	1,000,000	1,375	3	890,009	1,375	3	855,015
Time	$Exec.time_{min}$	0.03433	0.00050	11.21280	0.03444	0.00032	0.00012	0.03474	0.00032	0.00029
	$Exec.time_{max}$	0.07609	0.16397	14.00078	0.05924	0.01831	10.42652	0.05743	0.02480	10.35899
	Average $Exec.time$	0.03608	0.00232	11.48608	0.03676	0.00081	7.25192	0.03801	0.00091	7.36136
Speed up Q-L / DP Methods		318	4951	1	197	8953	1	194	8089	1

TABLE VI: Summary of 300 executions of the Dynamic Programming methods and the Q-Learning method to solve the decision-making problem of a UAV mission planning.

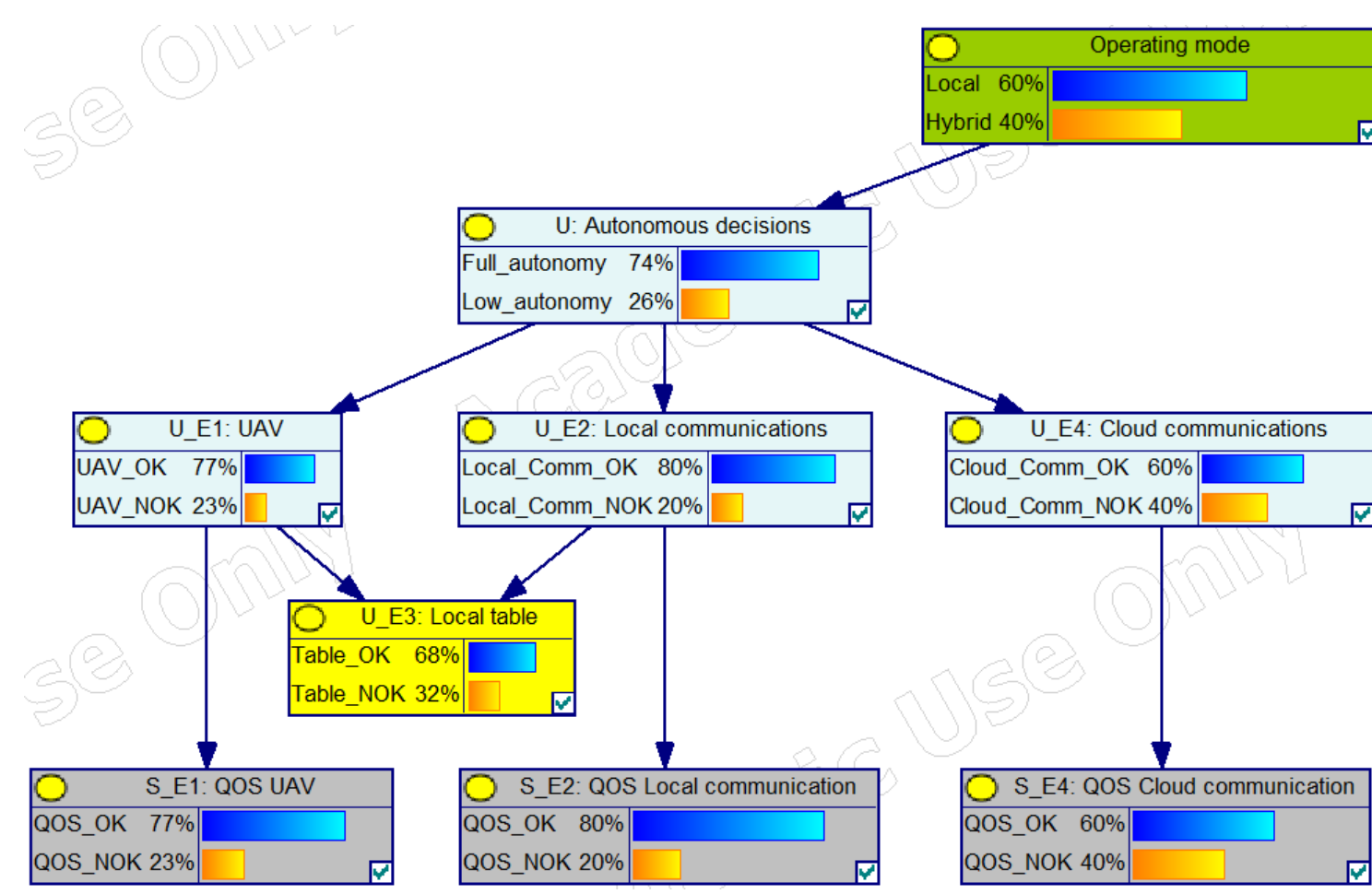
Execution time in seconds		Speed up QI / DP Method
Using V.I.	Average(T_{Nav})	0.0018
		7.8 1052
Using P.I.	Average(T_{Nav})	0.00019
		73.7 9967
Using Q-L	Average(T_{Nav})	0.0140
	$iter_{max} = 1,000$	1
	$iter_{max} = 100,000$	1.8937

Mission planning of a UAV:

- ➔ Sophisticated case with irregular states.
- ➔ Actions are non-similar in each state of the problem.
- ➔ It is more difficult to set up the Q-Learning method, and so, DP methods are more efficient.

IV. Adaptation with cooperation through the cloud/the local network

- ❖ Cooperation within a UAV team can be necessary in case of UAV malfunctioning.
- ❖ Mode switching evaluated by BN:
 - ➔ **Local mode**: local data (+ neighbor data) are sufficient;
 - ➔ **Hybrid mode**: local data are insufficient or communications are compromised.
- ❖ Data used:
 - ➔ QoS UAV
 - ➔ QoS Local communication
 - ➔ QoS Cloud communication



References

- [1] Mohand Hamadouche, Catherine Dezan, David Espes, and Kalinka Branco. Comparison of value iteration, policy iteration and q-learning for solving decision-making problems. In *2021 International Conference on Unmanned Aircraft Systems (ICUAS)*.
- [2] Mohand Hamadouche, Catherine Dezan, and Kalinka RLJC Branco. Reward tuning for self-adaptive policy in mdp based distributed decision-making to ensure a safe mission planning. In *2020 50th Annual IEEE/IFIP International Conference on Dependable Systems and Networks Workshops (DSN-W)*, pages 78–85. IEEE, 2020.
- [3] Mohand Hamadouche, Catherine Dezan, David Espes, and Kalinka Branco. Online reward adaptation for mdp-based distributed missions. In *2023 ICUAS*.

III. Self adaptation based rewards tuning for mission planning [2, 3]

- ❖ Policy π is a (solution of an MDP) mapping from state space (S) to action space (A).
- ❖ Policy π is used to determine the optimal action given the current state.
- ❖ Change in action reward modifies the action associated with a state.
- ❖ Modification of the policy requires updating the action rewards.
- ❖ **Method principle**:

1. Definition of conflicts and constraints.
2. Definition of priorities (action/UAV).
3. Conflict management:
 - ✳ Reward computation:

$$Q^* = \begin{pmatrix} Q_{s_1, a_1} & Q_{s_1, a_2} & \dots & Q_{s_1, a_m} \\ \vdots & \vdots & \ddots & \vdots \\ Q_{s_n, a_1} & \dots & \dots & Q_{s_n, a_m} \end{pmatrix}$$

$$\pi^*(s) = \arg \max_a Q^*(s, a) \quad \forall s \in S$$

Constraint: can't perform action α in State s_i

Execute another action β ($A \setminus \{\alpha\}$).

$$V(s_i) = \max (Q(s_i, \cdot)^*) = Q(s_i, a_\alpha) \rightarrow V(s_i) = \max (Q(s_i, \cdot)^*) = Q(s_i, a_\beta) \rightarrow Q(s_i, a_\beta) > Q(s_i, a_\alpha)$$

$$Q^*(s, a) = R(s, a) + \gamma \sum_{s' \in S} T(s, a, s') V^*(s') \rightarrow R(s_i, a_\beta) + \gamma \times T(s_i, a_\beta, s') \times V^*(s') > Q(s_i, a_\alpha)$$

$$\rightarrow \text{New Reward } R(s_i, a_\beta) \geq Q(s_i, a_\alpha) - \gamma \times T(s_i, a_\beta, s') \times V^*(s') \rightarrow \text{New Policy } \pi^*$$

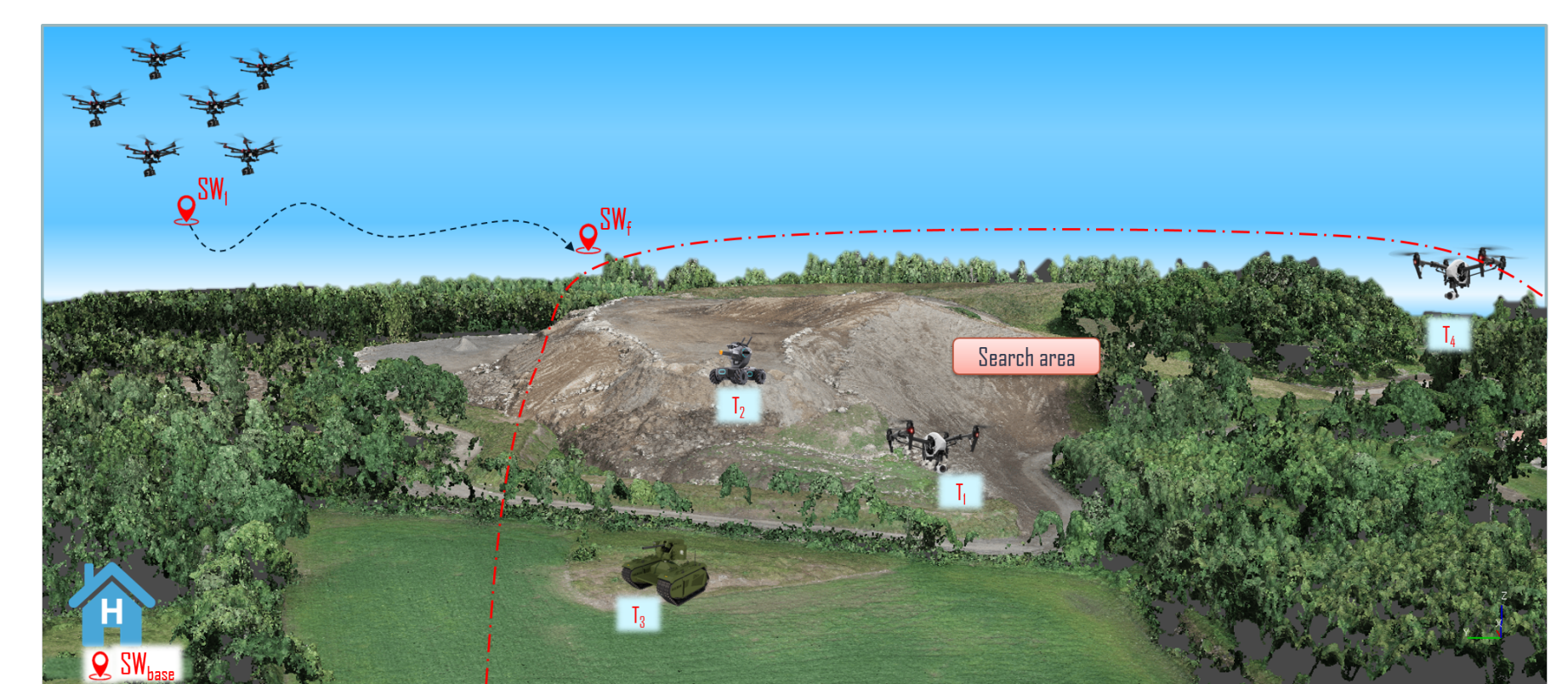
(a) **UAV level**:

- ➔ Executing simultaneous actions can lead to conflicts.
- ➔ Identification of conflicting states with antagonistic actions.
- ➔ Action-states with conflicts are adjusted by modifying the rewards of conflicting actions.

(b) **Multi-UAV level**:

- ➔ UAV decisions are unique and optimal at their level.
- ➔ Decisions can be contradictory and do not meet the mission's objectives of the mission.

- ➔ The UAV favors an alternative action to solve the conflict in the team.
- ➔ The method is efficient in terms of both latency ($\mu(\text{time})=2\text{ms}$) and energy consumption.



V. Conclusion

- ❖ Contributions:
 - ➔ Comparative study of methods for solving MDPs for mission planning.
 - ➔ Proposal of a systematic method for resolving conflicts at UAV and Multi-UAV team level.
 - ➔ Simulation of conflict resolution scenarios using the CoppeliaSim simulator.
 - ➔ Proposal of a method for adapting the UAV operating mode for conflict resolution by using the Cloud or the local network.

