An Embedded System Architecture based on Genetic Algorithms for Mission and Safety Planning with UAV

Jesimar S. Arantes, Márcio S. Arantes, Claudio F. M. Toledo, Onofre T. Júnior, Brian C. Williams

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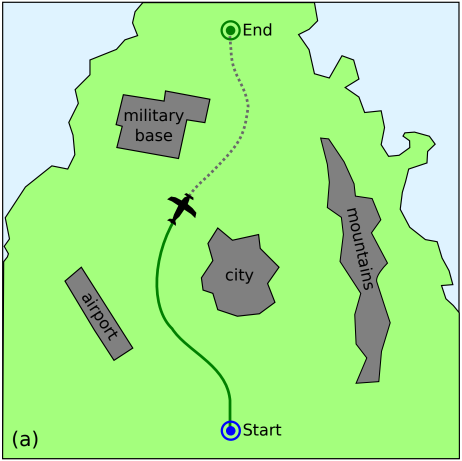
Outline

Introduction

This work addresses

- Path planning for mission execution with UAV:
  - Hybrid Genetic Algorithm for mission (HGA4m) (Arantes et al. 2016).
- Path replanning to land the UAV under critical situation:
  - Multi-Population Genetic Algorithm for security (MPGA4s) (Arantes et al. 2015).
- A combination of two architectures is proposed:
  - MOSA: Mission Oriented Sensor Array:
    - Supervision of mission systems;
    - Architecture create by (Figueira et al. 2013).
  - IFA: In-Flight Awareness:
    - Supervision of safety systems;
    - Architecture create by (Mattei et al. 2013).

Problem Description



- Path planning problem with chance constraints and obstacle avoidance
- Introduced by (Blackmore et al. 2011) and approached in (Arantes et al. 2016)

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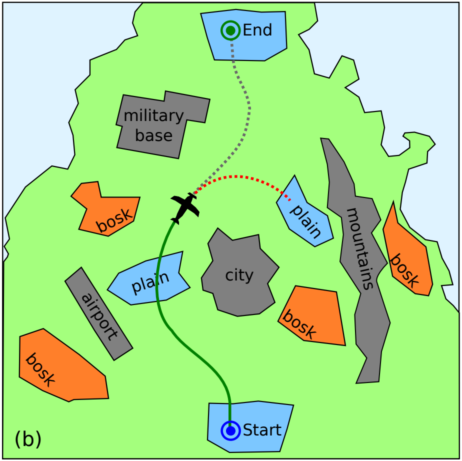

- Path replanning problem
- Approached in (Arantes et al. 2015)

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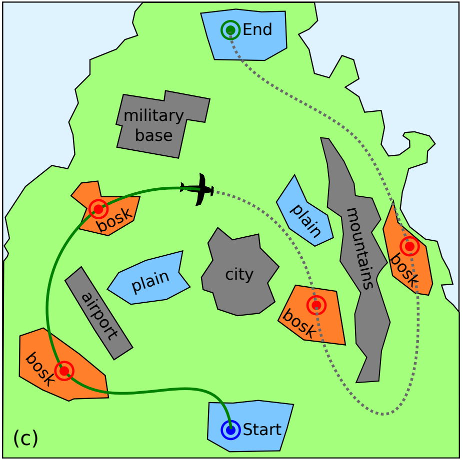
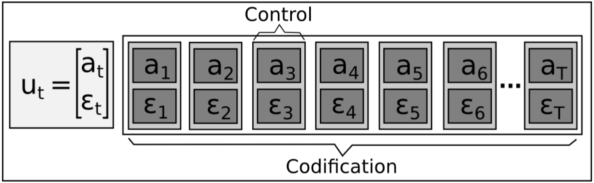


- Planning mission with system of safety
- Embedded in the same hardware architecture
- Approached in this work

Codification, Decodification and Solution

- Codification u_t:



Codification, Decodification and Solution

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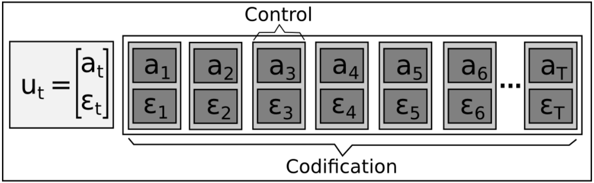

- Decodification F_Ψ:

$$x_{t+1} = F_\Psi(x_t, u_t)$$

$$\begin{bmatrix} p^x_{t+1} \\ p^y_{t+1} \\ v_{t+1} \\ \alpha_{t+1} \end{bmatrix} = \begin{bmatrix} p^x_t + v_t \cdot cos(\alpha_t) \cdot \Delta T + a_t \cdot cos(\alpha_t) \cdot (\Delta T)^2/2 \\ p^y_t + v_t \cdot sen(\alpha_t) \cdot \Delta T + a_t \cdot sen(\alpha_t) \cdot (\Delta T)^2/2 \\ v_t + a_t \cdot \Delta T - F^d_t \\ \alpha_t + \varepsilon_t \cdot \Delta T \end{bmatrix}$$

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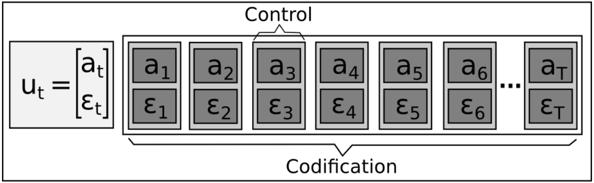

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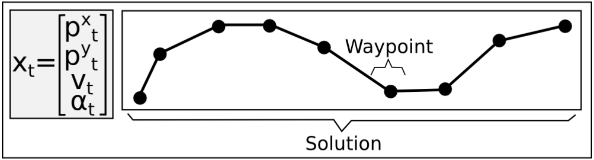
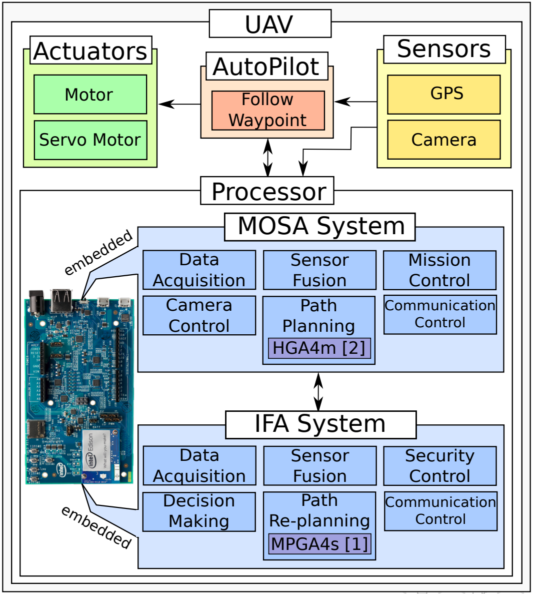
- Solution x_t:

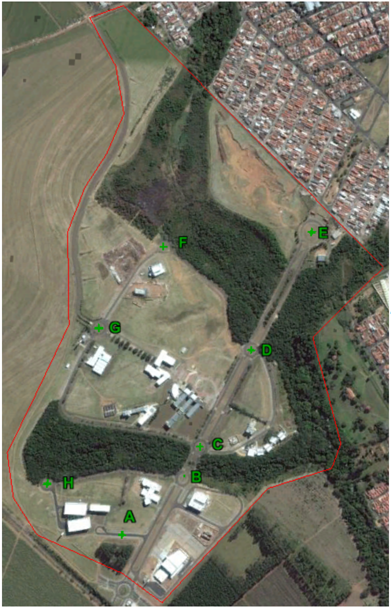


Methods



UAV
Actuators
Motor
Servo Motor
AutoPilot
Follow Waypoint
Sensors
GPS
Camera
Processor
embedded
MOSA System
Data Acquisition
Sensor Fusion
Mission Control
Camera Control
Path Planning
HGA4m [2]
Communication Control
IFA System
Data Acquisition
Sensor Fusion
Security Control
Decision Making
Path Re-planning
MPGA4s [1]
Communication Control
embedded

Problem Description



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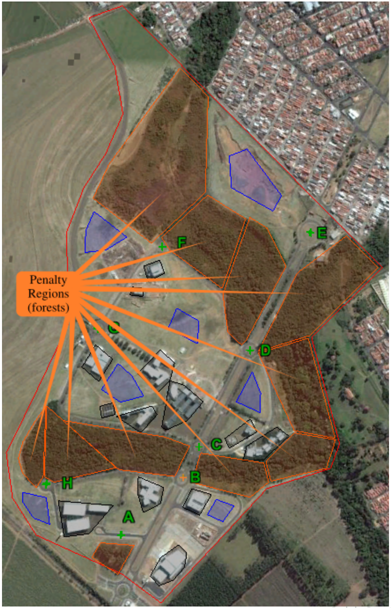

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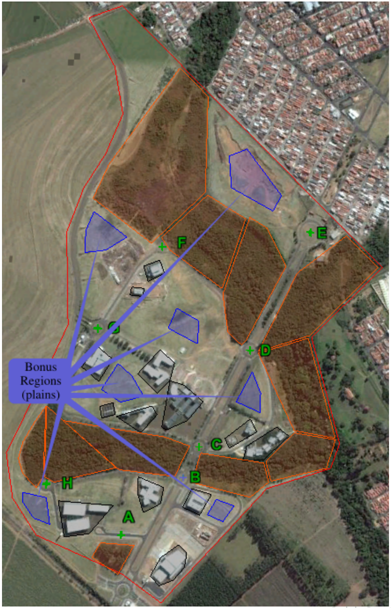

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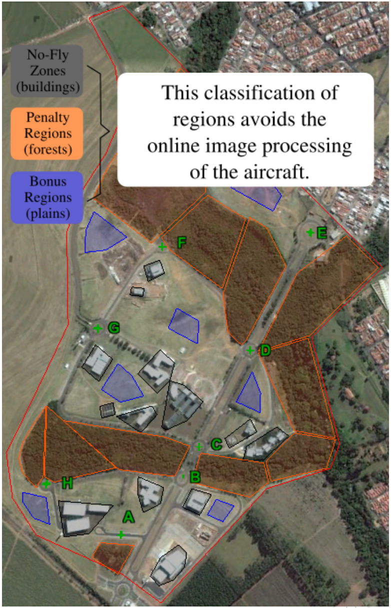

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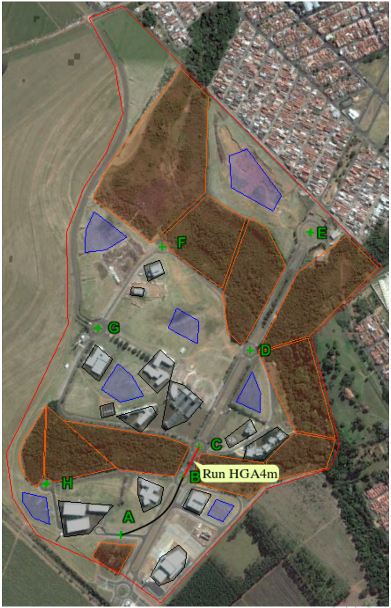

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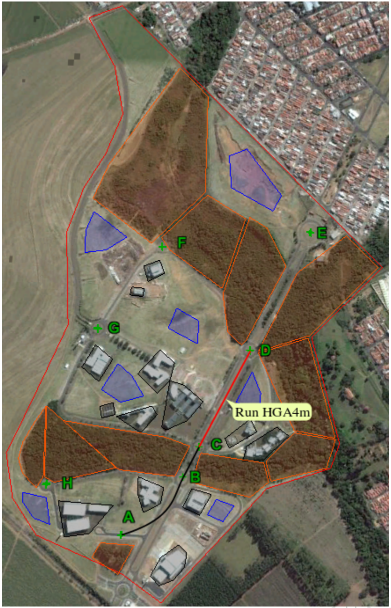

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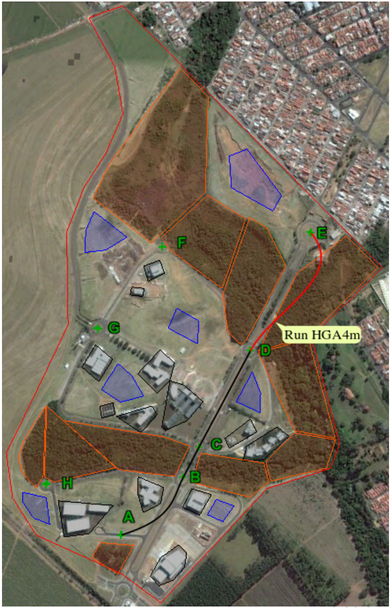

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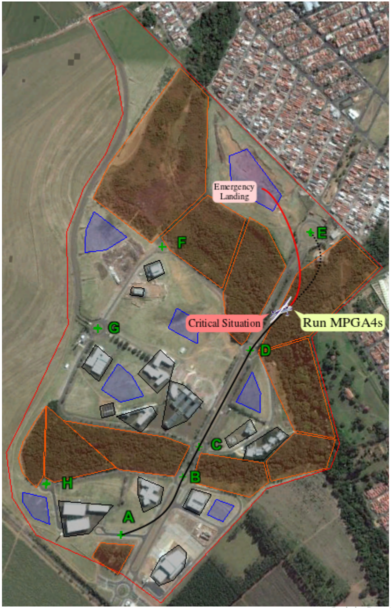
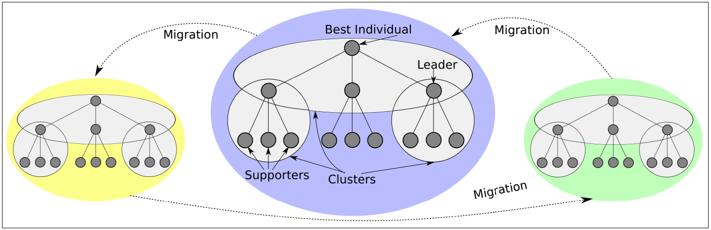


Computational Results

Table 1: Settings used in the HGA4m and MPGA4s method.

Parameters	Value HGA4m	Value MPGA4s
number of populations	3	3
population size	3x13	3x13
crossover rate	5	0.5
mutation rate	0.7	0.75
stopping criterion	10 sec	1 sec



Computational Results

- HGA4m
  - We evaluated 40 artificial maps in total
  - Stopping criterion 10 seconds
- MPGA4s
  - We evaluated 60 artificial maps in total
  - We evaluated 4 critical situations
  - Stopping criterion 1 second

	PC i5	Intel Edison
Frequency	1.8 GHz	500 MHz
Memory RAM	4 GB	1 GB
Operating System	Linux - Ubuntu	Linux - Yocto

Computational Results

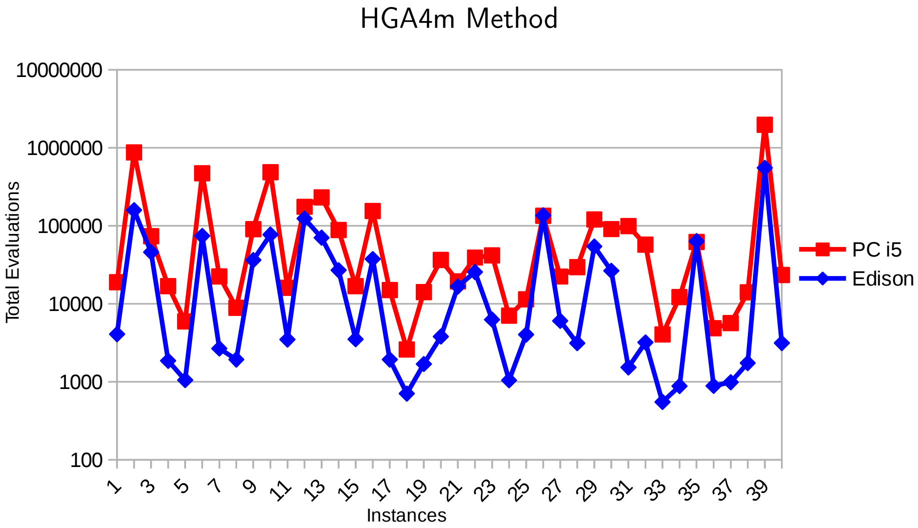


Figure 1: Number of evaluations by instance for path planning

Computational Results

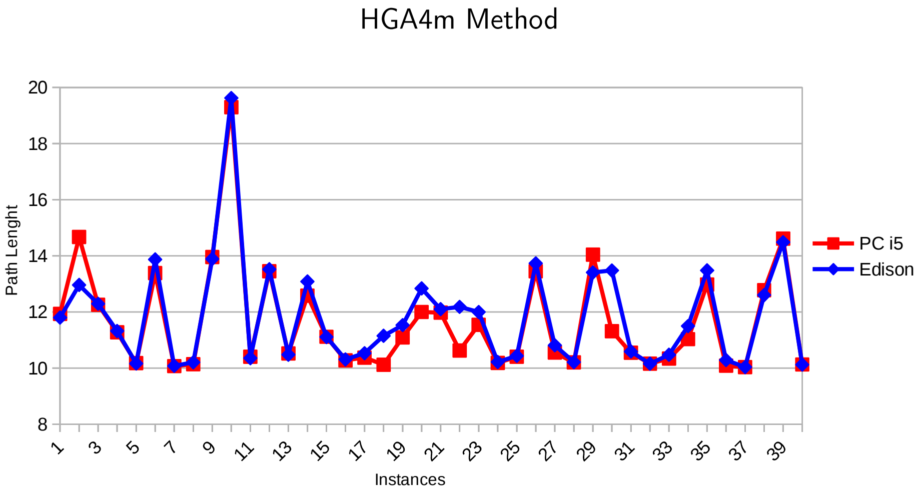


Figure 2: Path length by instance for path planning

Computational Results

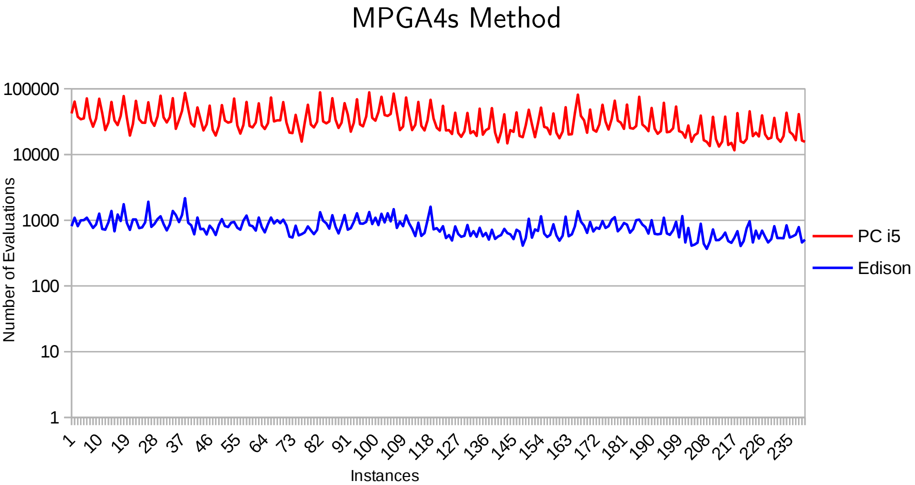
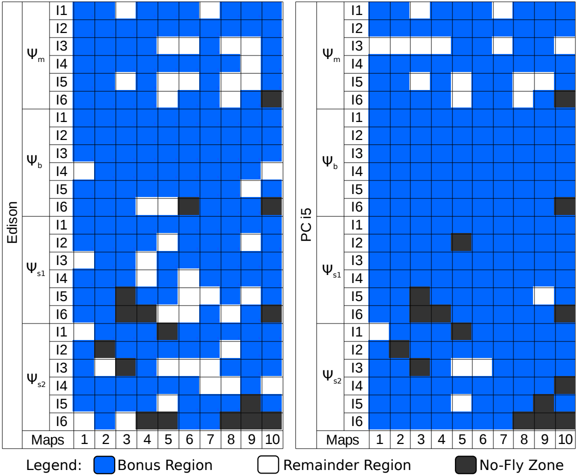


Figure 3: Number of evaluations by instance for path replanning.

Computational Results

MPGA4s Method

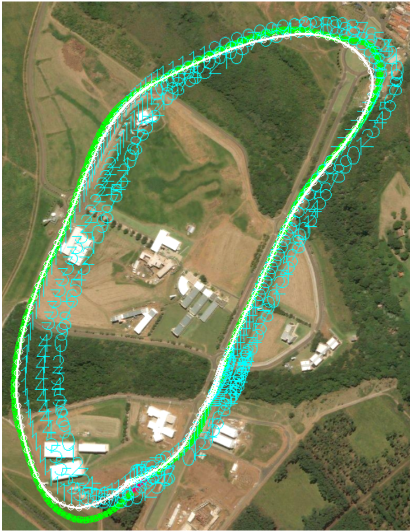


Region	PC i5	Edison
bonus	206 (85.8%)	181 (75.4%)
remainder	19 (7.9%)	43 (17.9%)
penalty	0 (0.0%)	0 (0.0%)
no-fly zone	15 (6.2%)	16 (6.6%)
total	240	240

Figure 4: Landing sites in both architectures for path replanning.

Computational Results

Video Simulation - SITL to validate routes.



Conclusions

- Despite differences in processing, the quality of the solution was similar.
- This indicates the robustness of GAs to find good solutions despite hardware limitations.
- In this way, GA can be embedded and aid the decision making during fully autonomous flights.

J. d. S. Arantes, M. d. S. Arantes, C. F. M. Toledo, and B. C. Williams.
A multi-population genetic algorithm for uav path re-planning under critical situation.
In *Tools with Artificial Intelligence (ICTAI), 2015 IEEE 27th International Conference on*, pages 486–493. IEEE, 2015.

M. d. S. Arantes, J. d. S. Arantes, C. F. M. Toledo, and B. C. Williams.
A hybrid multi-population genetic algorithm for uav path planning.
In *Proceedings of the 2016 on Genetic and Evolutionary Computation Conference*, pages 853–860. ACM, 2016.

L. Blackmore, M. Ono, and B. C. Williams.
Chance-constrained optimal path planning with obstacles.
IEEE Press, 2011.

N. M. Figueira.
Arranjos de sensores orientados à missão para a geração automática de mapas temáticos em VANTs.

Tese de doutorado, Universidade de Sao Paulo (USP), mar 2016.
Sao Carlos, SP.

A. L. P. Mattei.
Consciencia situacional em voo de sistemas aereos nao tripulados.
Tese de doutorado, Universidade de Sao Paulo (USP), ago 2015.
Sao Carlos, SP.

Acknowledgements

Email to contact:

jesimar.arantes@usp.br
{marcio, claudio, otj}@icmc.usp.br
williams@mit.edu

Thank You!