A Summary of Player Assessment in a Multi-UAV Mission Planning Serious Game

Víctor Rodríguez-Fernández, Cristian Ramirez-Atencia, and
David Camacho

Universidad Autónoma de Madrid (UAM) 28049, Madrid, Spain,
{`victor.rodriguez,cristian.ramirez`}`@inv.uam.es`,
`david.camacho@uam.es`
AIDA Group: `http://aida.ii.uam.es`

Abstract. Mission Planning for a large number of Unmanned Aerial Vehicles (UAVs) involves a set of locations to visit in different time intervals, and the actions that a vehicle must perform depending on its features and sensors. Analyzing how humans solve this problem is sometimes hard due to the complexity of the problem and the lack of data available. This paper presents a summary of a serious videogame-based framework created to assess the quality of the mission plans designed by players, comparing them against the optimal solutions obtained by a Multi-Objective Optimization algorithm.

Keywords: Mission Planning, Multi-UAV, Serious Game, Player Assessment, Multi-Objective.

1 Introduction

The study of Unmanned Aerial Vehicles (UAVs) is constantly increasing nowadays. These technologies offer many potential applications in numerous fields as monitoring coastal frontiers, road traffic, disaster management, etc [2]. Nowadays, these vehicles are controlled remotely from ground control stations by human operators who use legacy Mission Planning systems. The problem of Mission Planning for UAVs can be defined as the process of planning the waypoints to visit and the actions that the vehicle can perform (loading/dropping a load, taking videos/pictures, etc), typically over a time period.

The fast evolution of UAV systems is leading to a shortage of qualified operators. Thus, it is necessary to re-design the current training process to meet that demand, making UAV operations more accessible and available for a less limited pool of individuals, which may include high-skilled videogame players [4].

This work presents a summary of a previous work [6], focused on creating a videogame-based Multi UAV Mission Planning framework, that studies and compares human plans with those generated by a Mission Planning algorithm.

Modern approaches formulate the Mission Planning problem as a Constraint Satisfaction Problem (CSP) [1], where the mission is modelled and solved using constraint satisfaction techniques. CSPs are defined as a tuple <V,D,C> of variables $V = v_1, \ldots, v_n$; for each variable, a finite set of possible values D_i (its domain), and a set of constraints C_i restricting the values that variables can simultaneously take. In order to find optimal solutions for these problems, in this work an optimization function has been designed to search for good solutions minimizing the fuel consumption and the makespan of the mission. To solve this optimization problem, a Multi-Objective Branch & Bound (MOBB) algorithm [8] has been designed in order to find the optimal solutions in the Pareto Optimal Frontier (POF). This algorithm will be integrated in the developed framework to compare and rank the plans created by human players.

The rest of the paper is structured as follows: section 2 describes how a mission is defined in the UAV domain. Section 3 describes the game developed to simplify the Multi-UAV Cooperative Mission Planning Problem (MCMPP) problem and collect players Mission Plans. Section 4 explains the experiments performed and the experimental results obtained. Finally, last section presents the final analysis and conclusions of this work.

2 The Mission Planning Problem

The MCMPP is defined as a number n of tasks to accomplish for a team of m UAVs. There are different type of tasks, such as exploring a specific area or searching for an object in a zone. These tasks can be carried out thanks to the sensors available on the UAVs performing the mission. Each task is performed in a specific geographic *zone* and a specific *time interval*.

In addition, the vehicles performing the mission has some features that must be considered to check if a mission plan is correct. These features include the initial position, the initial fuel, the available sensors and one or more flight profiles. A flight profile specifies for a vehicle at a moment its speed, its fuel consumption rate and its altitude.

Figure 1 shows an assignment of a UAV u to two tasks i and j. In this assignment it is necessary to assure that u has enough fuel and the sensors needed to perform both tasks and then return to its initial position. To ensure this, it is necessary to compute the distance $d_{u \in i}$ from the initial position of u to the entry point of task i and then take the fuel consumption rate from the flight profile in order to compute the fuel consumed traversing this path. In addition, the speed v_u from the flight profile is used to compute the path duration.

Then, having the duration τ_i of task i and the speed $\overline{v_i}$ given by the flight profile of the sensor used to perform the task, we can deduce the distance traversed by the UAV during the task performance, and therefore, using the fuel consumption rate of sensor's flight profile, deduce the fuel consumed too. Next, the previous steps are repeated with task j.

Finally, it is necessary to compute the fuel consumption and flight time for the return of the UAV from the last task performed to its initial position.

When considering MCMPP as an optimization problem, the variables to minimize are the total **fuel consumption** and the **makespan** of the mission, i.e. the time elapsed since the mission start time until the mission is finished.

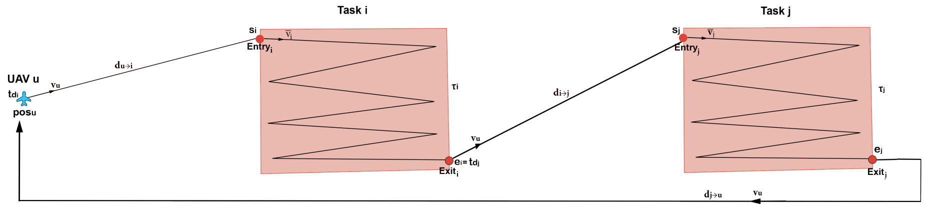


Fig. 1: Example of assignment of a UAV u to tasks i and j.

In previous works [5], we have modelled this problem as a CSP and automatically obtained a set of optimal solutions using a MOBB algorithm.

3 Developing a Mission Planning Videogame

The game created to accomplish the MCMPP problem has been designed focusing on the accesibility that professional mission planners lack of. It is based on the multi-UAV simulation environment *Drone Watch And Rescue*, that we designed in order to extract and analyze data from the user interactions [7].

Figure 2 shows a screenshot of Mission Planning Scenario in the game. This screen can be divided into five distinct parts:

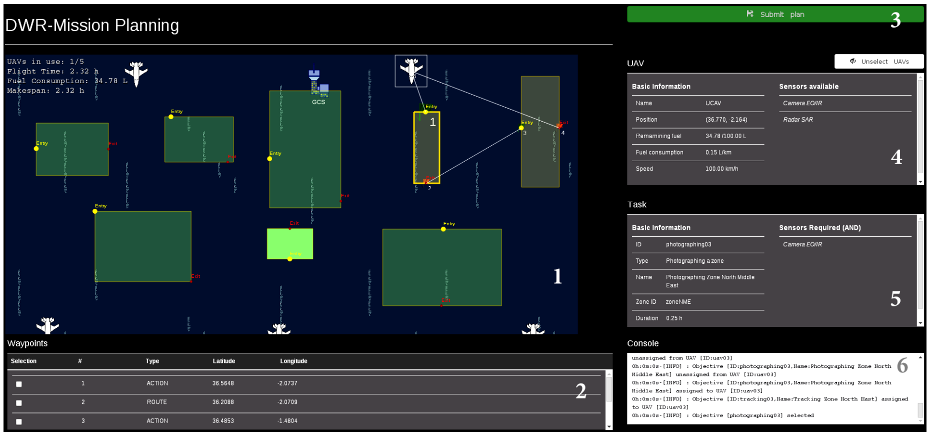
1. *Main Screen*: Displays graphically the Mission Scenario.
2. *Waypoints panel*: Shows the flying path of the selected UAV.
3. *Plan submission button*: Submits and saves the player's Mission Plan.
4. *UAV's panel*: Displays basic information and sensors of the selected UAVs.
5. *Task Panel*: Displays basic information and sensors of the selected task.
6. *Console Panel*: Logs the result of the player's interactions during a gameplay

To achieve an intuitive and quick understanding of the different controls available in the game, almost all of them are activated by doing mouse clicks on the game's *Main screen*. Below is detailed the whole set of game controls:

- *Select UAV*: Allows the player to see the UAV current path and information.
- *Select Task*: Allows the player to see the task information.
- *Assign/Unassign UAV to Task*
- *Submit Plan*: Submits and saves the current Mission Plan.

The game has been developed using web development technologies from the field of videogames. Their main advantages include the portability of the game between both desktop and mobile systems, and a high availability: using any web browser with HTML5 capabilities, a user can access the URL where the game is hosted and play it without installing any additional software.

However, it is important to note the limitations of this type of technologies. The system requirements on a videogame are much higher than those of a common web application, and current Javascript engines, despite being more and



DWR-Mission Planning

```
UAVs in use: 1/5
Flight Time: 2.32 h
Fuel Consumption: 34.78 L
Makespan: 2.32 h
```

Waypoints

Selection	#	Type	Latitude	Longitude
☐	1	ACTION	36.5648	-2.0737
☐	2	ROUTE	36.2088	-2.0709
☐	3	ACTION	36.4853	-1.4804

UAV

Basic Information		Sensors available
Name	UCAV	*Camera EO/IR*
Position	(36.770, -2.164)	*Radar SAR*
Remamining fuel	34.78 /100.00 L	
Fuel consumption	0.15 L/km	
Speed	100.00 km/h	

Task

Basic Information		Sensors Required (AND)
ID	photographing03	*Camera EO/IR*
Type	Photographing a zone	
Name	Photographing Zone North Middle East	
Zone ID	zoneNME	
Duration	0.25 h	

Console

```
unassigned from UAV [ID:uav03]
0h:0m:0s-[INFO] : Objective [ID:photographing03,Name:Photographing Zone North
Middle East] unassigned from UAV [ID:uav03]
0h:0m:0s-[INFO] : Objective [ID:photographing03,Name:Photographing Zone North
Middle East] assigned to UAV [ID:uav03]
0h:0m:0s-[INFO] : Objective [ID:tracking03,Name:Tracking Zone North East] assigned
to UAV [ID:uav03]
0h:0m:0s-[INFO] : Objective [photographing03] selected
```

Fig. 2: Game screenshot showing the Mission Scenario used in this work. Numbers represent the different parts of the Graphical User Interface (GUI)

more powerful, yet have notorious performance troubles when running compute-intensive jobs. Because of this, the game has been designed with a 2-level architecture (server-client), based on the design patterns used in the development of multi-user real time applications and videogames [3]. Client-Server communication is achieved by the use of the *Websockets* communication protocol, which offers lower latency than HTTP, and is specially suitable for real time data streams. For more information about the architecture, see [7].

4 Experimentation

In this work, the main goal of the experimentation is to rank the quality of the Mission Plans designed by players in the video game described in section 3 against those obtained automatically and optimally by a MOBB algorithm, detailed in the complete work [6].

The Mission Scenario used in this experiment features 8 tasks to be assigned to 5 UAVs scattered throughout the map. A graphical representation of this Mission Scenario can be seen, as a game screenshot, in Figure 2.

In this scenario, we must compute the optimal mission plans in terms of the variables *Makespan* and *Fuel Consumption*. For this aim, we used the MOBB algorithm developed in [6] to find the Makespan-Fuel consumption POF of the biobjective problem. We obtain that for the proposed scenario, the POF is composed of **six optimal solutions**.

To evaluate the quality of a player's Mission Plan, we get its Makespan and Fuel consumption values, normalize them into $[0, 1]$, and then compute the *Euclidean distance* of such values to the also normalized Makespan-Fuel consump-

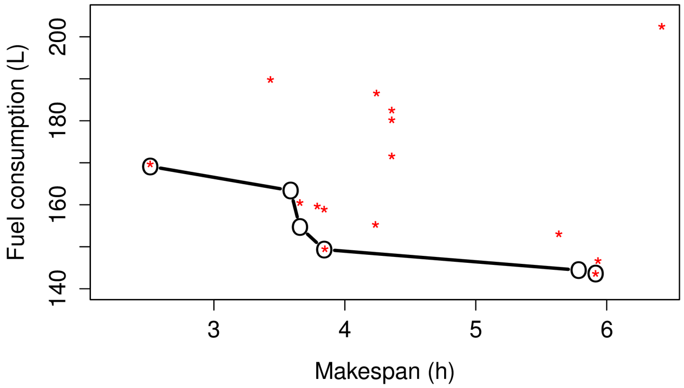


Fig. 3: Comparison between player mission plans (red points) against the computed Pareto Optimal Frontier for variables Makespan and Fuel Consumption.

tion POF calculated before. The player's plan quality will represent his *score* in the game, and will allow us to compare gameplays.

To carry out this experiment, a set of 15 players submitted a Mission Plan playing the video game developed. None of them had knowledge in the field of MCMPP, and only received a brief tutorial about the game objective and the game controls. Figure 3 shows the performance of each player's gameplay as a point in the Makespan-Fuel space. The closer a point is to the POF, the better rank the player will have. Table 1 shows the first ranking positions numerically. The complete ranking is shown in [6].

The results prove there is not a dominant planning style in terms of the optimization variables focused by the players. Most of the points are located at the center of the space, which means that the general trend that a novice player follows in this type of problems is balancing the values to optimize. It is also remarkable that the Mission Plans are generally quite close to the POF.

5 Conclusions and Future Work

This paper has presented a summary of the contributions made by some published works in the field of the Multi-UAV Cooperative Mission Planning Problem, specially focused on assessing user performance when designing plans. A video-game based framework is created to make this problem understandable for non-expert users, and to rank and compare player plans against the optimal ones computed by a Multi-Objective Optimization algorithm.

As future work, we intend to extend the video game to allow the creation of more complex plans, to introduce some gamification elements (as tutorials and levels) that make it even more accessible, and to include elements that

Table 1: Top 5 player ranking. The less score the better ranking position

Ranking	Makespan (h)	Fuel consumption (L)	Score
1	5.91	**143.59**	**0.00000**
2	3.85	149.45	0.00052
3	**2.51**	169.63	0.00213
4	3.66	160.44	0.01014
5	5.93	146.66	0.01405

improve the analysis of the players, as identifications to track the evolution of their gameplays, or time spent measurements to rank the player's speed.

Acknowledgments

This work is supported by the Spanish Ministry of Science and Education under Project Code TIN2014-56494-C4-4-P, Comunidad Autonoma de Madrid under project CIBERDINE S2013/ICE-3095, and Savier an Airbus Defense & Space project (FUAM-076914 and FUAM-076915). The authors would like to acknowledge the support obtained from Airbus Defence & Space, specially from Savier Open Innovation project members: José Insenser, Gemma Blasco, César Castro and Juan Antonio Henríquez.

References

1. Guettier, C., Allo, B., Legendre, V., Poncet, J.C., Strady-Lecubin, N.: Constraint model-based planning and scheduling with multiple resources and complex collaboration schema. In: Procedings of the Sixth International Conference on Artificial Intelligence Planning Systems (AIPS). pp. 284–292 (2002)
2. Kendoul, F.: Survey of advances in guidance, navigation, and control of unmanned rotorcraft systems. Journal of Field Robotics 29(2), 315–378 (2012)
3. Lewis, M., Jacobson, J.: Game engines. Communications of the ACM 45(1), 27 (2002)
4. McKinley, R.A., McIntire, L.K., Funke, M.A.: Operator selection for unmanned aerial systems: comparing video game players and pilots. Aviation, space, and environmental medicine 82(6), 635–642 (2011)
5. Ramirez-Atencia, C., Bello-Orgaz, G., R-Moreno, M.D., Camacho, D.: Branching to find feasible solutions in Unmanned Air Vehicle Mission Planning. In: International Conference on Intelligent Data Engineering and Automated Learning. pp. 286–294 (2014)
6. Rodríguez-Fernández, V., Atencia, C.R., Camacho, D.: A Multi-UAV Mission Planning Videogame-based Framework for Player Analysis. In: Evolutionary Computation (CEC), 2015 IEEE Congress on. IEEE, In press (2015)
7. Rodríguez-Fernández, V., Menéndez, H.D., Camacho, D.: Design and Development of a Lightweight Multi-UAV Simulator. In: Cybernetics (CYBCONF), 2015 IEEE International Conference on. IEEE, In press (2015)
8. Rollon, E., Larrosa, J.: Constraint optimization techniques for multiobjective branch and bound search. In: International Conference on Logic Programming, ICLP (2008)