A Multi-UAV Simulator for User Data Analysis

Author: Víctor Rodríguez Fernández

Advisor: David Camacho Fernández

A thesis submitted in partial fulfillment for the Master Degree on
Research and Innovation in Information and Communication Technologies

in the
Escuela Politécnica Superior
Departamento de Ingeniería Informática

February 2015

"There's just nothing better than a beard"

The Beards

Abstract

Escuela Politécnica Superior
Departamento de Ingeniería Informática

Master on Research and Innovation in Information and Communication Technologies

by Víctor Rodríguez Fernández

English Abstract

Keywords

Unmanned Aircraft Vehicles, Simulator, Videogames, Behavior analysis

Resumen

Escuela Politécnica Superior
Departamento de Ingeniería Informática

Máster en Investigación e Innovación de las Tecnologías de la Información y las Comunicaciones

por Víctor Rodríguez Fernández

Spanish Abstract

Palabras Clave

Sistemas Aéreos no tripulados, Planificación de Misiones, Simulador, Análisis de comportamiento

Acknowledgements

Acknowledgements

Contents

List of Figures

List of Tables

Abbreviations

AI	**A**rtificial **I**ntelligence
BT	**B**ack**T**racking
CSOP	**C**onstraint **S**atisfaction **O**ptimization **P**roblem
CSP	**C**onstraint **S**atisfaction **P**roblem
GA	**G**enetic **A**lgorithm
GCS	**G**round **C**ontrol **S**tation
HCI	**H**uman **C**omputer **I**nterface
IA	**I**nterval **A**lgebra
POF	**P**areto **O**ptimal **F**rontier
TCSP	**T**emporal **C**onstraint **S**atisfaction **P**roblem
UAS	**U**nmanned **A**ircraft **S**ystem
UAV	**U**nmanned **A**ir **V**ehicle

Chapter 1

Introduction

1.1 Motivation

1.2 Objectives

1.3 Document structure

Chapter 2

Related Work

The study of Unmanned Air Vehicles (UAVs) is wide and goes

In this chapter, we introduce a state of the art on UAV Mission Simulators (UMSs), focusing on their main features, objectives, complexity and accessibility.

2.1 UAV Simulators

Computer simulations, and their extension into videogames, of Unmanned Systems (USs) are an emerging topic. There are at least three motivations for these type of simulators. One is the role of simulators in adoption of new technology, another is their potential for low cost training, and finally their utility in research. The four critera used to jugde the quality of any virtual simulator are defined in [1]:

1. *Physical Fidelity*: It can be described as the extent to which the virtual environment emulates the real world. A simulator with high physical fidelity is able to render the environment with high resolution textures, shaders, lighting, reflection, and bump mapping. A low physical fidelity simulator uses 2D rendering and no sound is required.

2. *Functional Fidelity*: The degree to which the simulation acts like the operational equipment in reacting to the tasks executed by the trainee. High functional fidelity is defined as the simulation of most of the forces acting on a vehicle and its actuators including gravity, drag, and accelerations from motors and collisions

on specific elements of the vehicle. A low functional fidelity simulator does not simulate forces applied to the vehicle but only velocities or absolute position.

3. *Ease of Development*: It is defined by how easy/difficult the simulator can be modified, and the available documentation from the author.

4. *Cost*: For a simulator to be useful it must not be time consuming to install or run and accessible in terms of initial monetary cost for both the developer and end user. The simulator developed in this work is focused on maximizing this criteria.

[2] surveys multiple US simulators, both commercial and open-source, and provides a subjective rating of capabilities in terms of physical fidelity, functional fidelity, ease of use, and cost. For the purposes of this work, we focus only on those rated as "Low" in the Cost criteria. Table 2.1 summarizes the rating results of the aforementioned "Low cost" US Simulators:

- *FlightGear*: FlightGear [3] is a 3D open source simulator, very realistic and focused on simulating the flight of a single aircraft vehicle. It is available as a free download under GPL license. The entire source code is available for modification and is under constant development. The application runs on Windows, Mac, and Linux operating systems. It has been used for various academic projects. For example, Summers, et al. in [4] used FlightGear to simulate a UAV carrying environmental sensors and Cervin, et al. in [5] used FlightGear to create an interface for a real UAV.

- *Simbad*: Simbad [6] is a Java 3d robot simulator for scientific and educational purposes. It is mainly dedicated to researchers/programmers who want a simple basis for studying Situated Artificial Intelligence, Machine Learning, and more generally AI algorithms, in the context of Autonomous Robotics and Autonomous Agents. It is not intended to provide a real world simulation and is kept voluntarily readable and simple.

- *SimRobot*: SimRobot [7] is a physics based robot simulator with a 3D OpenGL based display. Several sensor types are supported, including cameras, range sensors, touch sensors, and actuator state. It was used by the German team for the 2005 RoboCup competition [8].

Analyzing the simulators detailed above, it is appreciable that the Functional Fidelity rating for all of them is not high, thus we cannot use them to easily analyze human control over them. Also, none of them focuses on the field of UAVs purely, but cover general unmanned robots or aircrafts instead. This is because at the time when these simulators were released, UAVs did not have as much importance as now.

Recently, the rapidly increasing interest in UAVs has caused that they are no longer part of a flight simulator or a type of robot in a general robot simulator. Small/micro UAVs have become applicable in civilian circumstances like remote sensing, mapping, traffic monitoring, search and rescue, etc. They are expendable, easy to be built and operated. Most of them can be operated by one to two people, or even be hand-carried and hand-launched [9, 10]. This has caused a large increase in the development of the so-called *Autopilots*.

Autopilots are systems to guide the UAVs in flight with no assistance from human operators, consisting of both hardware and its supporting software. In [11], both commercial and research autopilot systems for small UAVs are reviewed and discussed in detail. Since this work is not emphasized on hardware, the most remarkable autopilot from that survey, in terms of software development, is *Paparazzi*.

Paparazzi [12] is an open-source project, very popular among researchers, highlighted by offering good flexibility and ease to modify the autopilot based on own requirements (High ”Ease of development” rate, following the criteria of [1]). For the software, it can achieve waypoint tracking, auto-takeoff and landing, and altitude hold. Figure **??** shows how this software tries to imitate a real Ground Control Station (GCS). A disadvantage of Paparazzi (and more generally, of all autopilots surveyed in [11]), is the lack of support for cooperative control functions, required for some large area tasks that need multiple UAVs to perform them.

TABLE 2.1: A comparison of available Low-Cost Unmanned Vehicle Simulators.

Simulator	**Physical Fidelity**	**Functional Fidelity**	**Ease of Development**	**Cost**
FlightGear	High	Medium	Medium	Low
Simbad	Medium	Low	Medium	Low
SimRobot	Medium	Low	Medium	Low

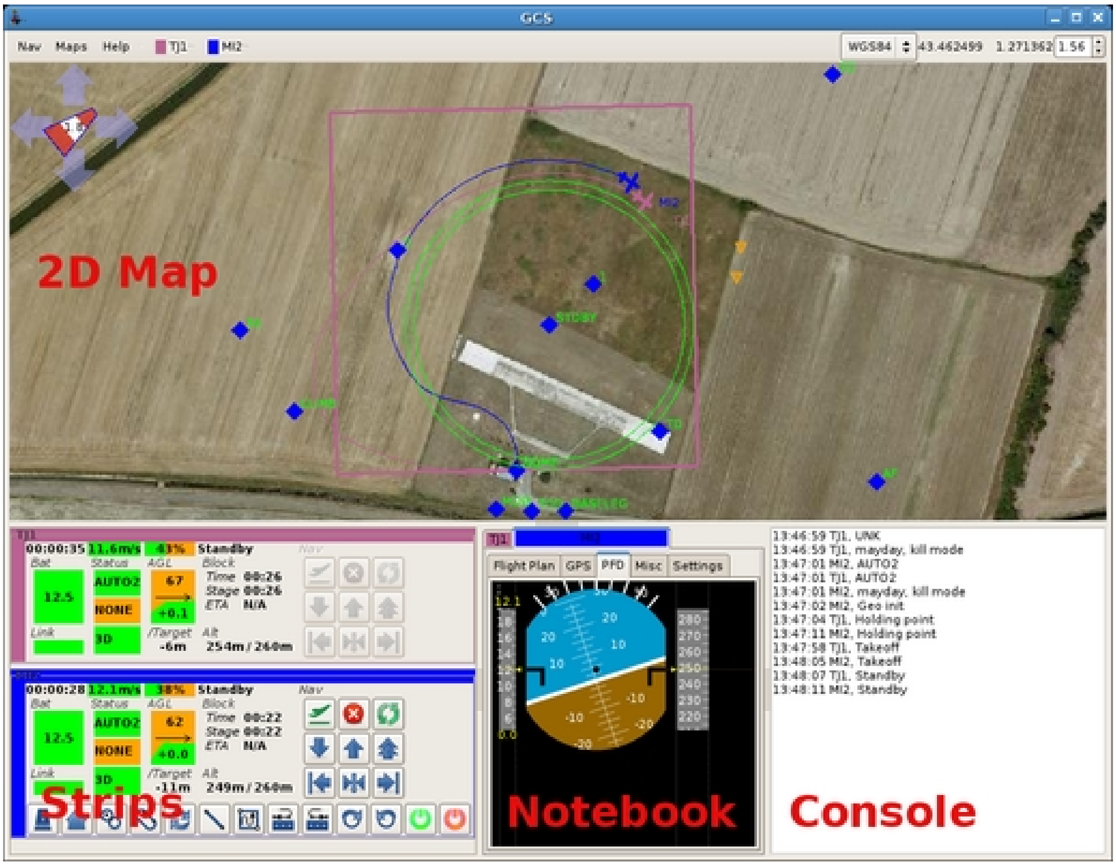

FIGURE 2.1: Paparazzi GCS. The Paparazzi Ground Control Station is the heart of the system and the user's primary interaction interface.

2.1.1 Multi-UAV Simulators

2.1.2 Gamification in UAV Simulators

2.2 User Profile Analysis

Computer simulation and video games are pedagogically proven techniques for training. Recent studies have shown that game-based learning have the potential to improve the transfer of skills over classroom-based activities [1, 13, 14].

2.2.1 Behavior Analysis in Video games

Appendix A

DWR Dataset

This appendix shows the entire dataset used to save the data from a simulation executed by the simulator *Drone Watch And Rescue*. The Data Base Management System used to store this dataset is *MongoDB*, and hence the data is organized into collections.

Collection	Field	Format	Description
Simulations	_id	ObjectId	MongoDB unique identifier
Simulations	clientIP	String	Player's IP address
Simulations	createdAt	Date	Simulation start date
Simulations	environmentId	Number	An identifier of the environment used in this simulation
Simulations	missionPlanId	Number	An identifier of the mission plan used in this simulation
Simulations	incidentSchedulingId	Number	An identifier of the incident schedule used in this simulation
Simulations	targetsDefinitionId	Number	An identifier of the targets definition used in this simulation
SimulationSnapshots	_id	ObjectId	MongoDB unique identifier
SimulationSnapshots	simulation_id	ObjectId*	Reference to the associated simulation
SimulationSnapshots	simulationElapsedTime	Number	Time (in ms), measured from the beggining of the simulation timeline, in which the snapshot was taken.
SimulationSnapshots	realElapsedTime	Number	Time (in ms), measured from the beggining of the real timeline, in which the snapshot was taken.
Simulations	simulationSpeed	Number	Current simulation speed (min. value = 1)
Simulations	event	ObjectId*	Reference to the event that caused this snapshot.

Bibliography

[1] Amy L Alexander, Tad Brunyé, Jason Sidman, and Shawn A Weil. From gaming to training: A review of studies on fidelity, immersion, presence, and buy-in and their effects on transfer in pc-based simulations and games. *DARWARS Training Impact Group*, 5:1–14, 2005.

[2] Jeff Craighead, Robin Murphy, Jenny Burke, and Brian Goldiez. A survey of commercial & open source unmanned vehicle simulators. In *Robotics and Automation, 2007 IEEE International Conference on*, pages 852–857. IEEE, 2007.

[3] Flightgear. URL http://www.flightgear.org. [Online].

[4] Phil Summers, Dave Barnes, and Andy Shaw. Determination of planetary meteorology from aerobot flight sensors. In *Proceedings of 7th ESA Workshop on Advanced Space Technologies for Robotics and Automation*, 2002.

[5] B Cervin, C Mills, and BC Wünsche. A 3d interface for an unmanned aerial vehicle. *SE Stage*, 4, 2004.

[6] Simbad, . URL http://simbad.sourceforge.net/. [Online].

[7] Simrobot, . URL http://www.informatik.uni-bremen.de/simrobot/index_e.htm. [Online].

[8] Tim Laue, Kai Spiess, and Thomas Röfer. Simrobot–a general physical robot simulator and its application in robocup. In *RoboCup 2005: Robot Soccer World Cup IX*, pages 173–183. Springer, 2006.

[9] Unmanned Aerial Vehicles Roadmap. Roadmap 2002-2027. *US DoD, December*, 2002.

[10] Huaiyu Wu, Dong Sun, and Zhaoying Zhou. Micro air vehicle: Configuration, analysis, fabrication, and test. *Mechatronics, IEEE/ASME Transactions on*, 9(1): 108–117, 2004.

[11] HaiYang Chao, YongCan Cao, and YangQuan Chen. Autopilots for small unmanned aerial vehicles: a survey. *International Journal of Control, Automation and Systems*, 8(1):36–44, 2010.

[12] Pascal Brisset, Antoine Drouin, Michel Gorraz, Pierre-Selim Huard, and Jeremy Tyler. The paparazzi solution. In *MAV 2006, 2nd US-European Competition and Workshop on Micro Air Vehicles*, pages pp–xxxx, 2006.

[13] Alexander Lewis Aitkin et al. Playing at reality: Exploring the potential of the digital game as a medium for science communication. *Made available in DSpace on 2011-01-04T02: 37: 23Z (GMT). No. of bitstreams: 7 02whole. pdf. jpg: 1881 bytes, checksum: ac88eea70013e083ecb0c5330e53e7a2 (MD5) 01front. pdf. jpg: 1881 bytes, checksum: ac88eea70013e083ecb0c5330e53e7a2 (MD5) 02whole. pdf. txt: 563958 bytes, checksum: 5e41da750d4369fa13d0fba08ad6a048 (MD5) 01front. pdf. txt: 12659 bytes, checksum: 0481a3322578325d8221eb983ac49324 (MD5) 01front. pdf: 121957 bytes, checksum: 0856401293636ffe92a2dd3a295de446 (MD5) 02whole. pdf: 1742623 bytes, checksum: 91119639a4629d5f2f62aaaf8a2c1126 (MD5) license. txt: 1972 bytes, checksum: 659aa5e507bf4ef21d5059f70f34b19c (MD5) Previous issue date: 2008-01-14T05: 43: 23Z*, 2004.

[14] C Shawn Green and Daphne Bavelier. Action video game modifies visual selective attention. *Nature*, 423(6939):534–537, 2003.