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Use of deterministic AI and a multi-user virtual test environment for drone inspection mission safety

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***Abstract*—One of the major challenges of integrating AI in UAV control is the ability of the pilot to effectively interact with the system. Inspired by process-control and vigilance devices, this work employs a predictable and deterministic form of AI to enable single-crew (i.e. pilot) operation in an unconstrained dynamic environment. A multi-user simulation environment was developed in Unity to validate the mission and to train and evaluate pilot-automation interactions. Preliminary simulation results for an inspection case study at the Clifton Suspension Bridge are reported.**

***Index Terms*—UAV, HMI, Virtual Environment, AI**

I. Introduction

The use of Artificial Intelligence (AI) for UAV control may reduce operator workload and aid decision making [1]. Difficulties in the use of AI for flight control include: encumbrance on the pilot's working memory by having to predict future states [2], [3], breakdown of pilot-automation coordination due to inaccuracies in the pilot's mental system model [4], reduced pilot vigilance and ability to intervene in case of AI failure [5], [6]. However, improvements can be made by training the pilot on the system [7].

This work proposes a two-stage approach to improve mission safety of UAVs in complex surroundings: (1) control using deterministic automation with simple redundant behaviour patterns (2) an immersive multi-user simulation environment for pilot rehearsal and visualisation of the mission and control design. A pilot and an instructor may interact concurrently within the environment enabling an instructor to test a pilot on their response to events such as pedestrians entering the flight zone or glitches in the drone hardware. The use of predictable automation reduces the load on pilot's working memory, and mission rehearsal allows the pilot to improve their mental model of the system. These factors reduce the likelihood of an 'automation surprise' and improve the overall mission safety.

II. Background

Basic drone automation includes flight stabilisation and waypoint following. When operating in complex environments, there is a need to monitor drone health and events on the ground and react correspondingly [8]. This is often a demanding task, and failure to do so can compromise public safety. In this work, we adopt a ground control automation (GCA) [9] that can assist the pilot with drone health monitoring and incorporate pilot judgement to proceed with mission segments.

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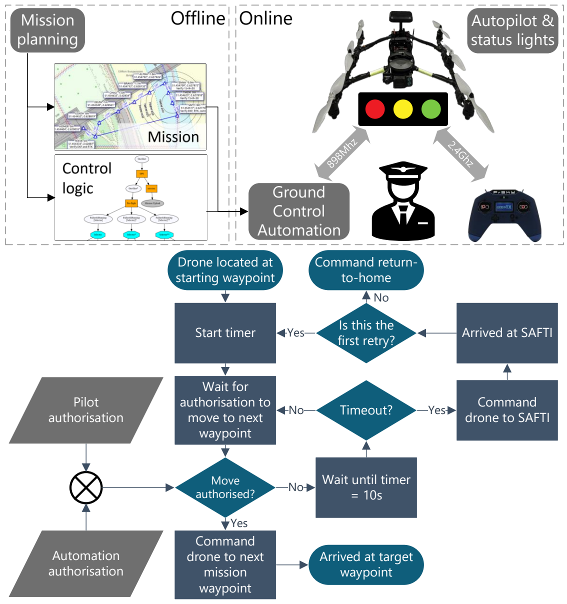

Fig. 1: An overview of the drone system (top) and GCA logic (bottom)

Real-time development engines provide developers with the tools to produce interactive, 3D simulations with network capabilities and high quality graphics. Networked simulations enable multiple users to interact with an environment simultaneously from around the world. Such environments facilitate complex spatial, physical, and logical interactions, providing users with opportunities to make high-level decisions during interaction with the simulation and other users.

III. Methods

A. Ground Control Automation

Fig. 1 shows an overview of the drone system with the underlying GCA logic. The GCA augments a waypoint mission by adding an authorisation step to each mission leg. This starts with a GCA check of vital drone subsystems and reporting through a 'traffic light' style status indicator on the drone. If the pilot determines the flight area to be free of hazards, they can approve the move by pressing a single switch on the transmitter. If the move is not authorised by the pilot or the GCA, the drone is flown to a safe waypoint called 'SAFTI', which is away from known hazards and structures. The HMI lights follow existing colour coding guidelines [10]

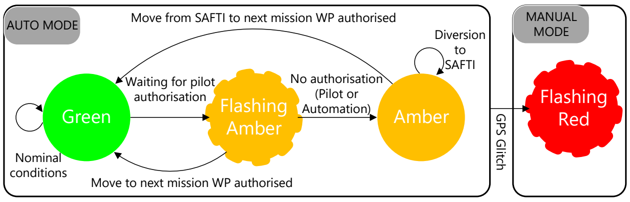

Fig. 2: State diagram illustrating the on-board light sequence seen by the pilot

with red indicating inoperable conditions, amber indicating unsatisfactory but operable conditions, and green indicating satisfactory conditions across all subsystems. As the decision to proceed is shared between the pilot and automation, the HMI uses a flashing light status to indicate when pilot response is needed. Fig. 2 shows the state transitions of the HMI lights. Note that flashing red is only used in a GPS glitch scenario where the autopilot navigation capability is compromised and a manual takeover is needed.

B. *Multi-user simulation training environment*

A Multi-fidelity Airspace and Platform Simulation (MAPS) was developed in Unity to facilitate the practice of decision making in drone missions. The HMI was implemented using a point light and a mesh with an emissive material. The scene included: a high quality model of Clifton Suspension Bridge (provided by Vu.City), pedestrians, and a UAV. A tool was developed to import and visualise the waypoints from the final mission design. The multi-user environment was developed using third party networking code (Photon PUN). Users are able to join the simulation as a pilot or an instructor/assessor. Each user sees an overlay displaying UAV health information. The pilot is positioned at one end of the bridge and may rotate their view to observe the scene as though they were standing in the scene. The pilot interacts with the GCA via key presses to provide authorisation, manual override, and control inputs to the UAV. The instructor is able to move around the scene freely to observe from all angles. The instructor is able to assess judgement calls of the pilot by spawning pedestrians to walk on the bridge.

IV. Illustrative Example

Fig. 3 shows a case study drone inspection of the Clifton Suspension Bridge within the MAPS environment. The multi-user setting allowed the instructor to introduce a pedestrian incursion at B and a GPS glitch at D. The pilot can then experience and respond to these events, rehearsing the mission in a safe, virtual environment. The overall experience can aid in forming a complete and correct mental model of the system.

V. Conclusions & Future Work

Initial simulation results demonstrate feasibility in capturing a complex dynamic environment along with underlying

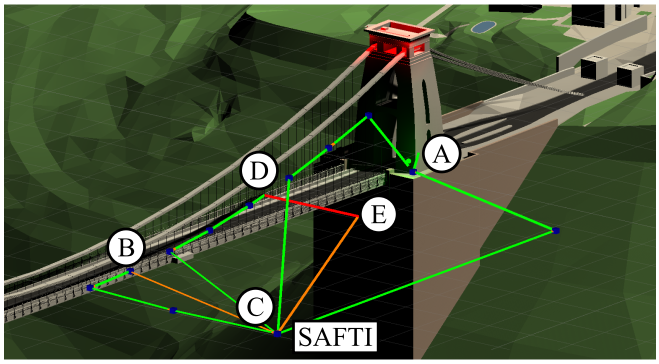

Fig. 3: An example scenario showing: A) Start of the mission. B) Pedestrian spotted by pilot who did not give authorisation to proceed, the GCA timed out and moved the drone to SAFTI. C) Pilot gave authorisation to proceed from SAFTI. D) Pilot took control of the drone manually after a GPS glitch. E) Pilot resumed GCA 'AUTO' mode and the mission continued.

automation design. This work demonstrated the utility of real-time, multi-user simulation environments for mission rehearsal and validation. Pilot-automation interactions can be practised and tested in a range of complex scenarios which may be otherwise difficult to simulate. The virtual environments facilitate high level decision making and enable assessment of pilot judgement.

Future work includes the participation of drone pilots for workload evaluation; additional event triggers for instructors such as spawning cars or recreational drone users. Multi-user test environments may be adopted for safety case proposals with governing bodies observing and testing mission rehearsals in real-time. The simulated environments can also be adapted for virtual reality applications.

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