Robotic Relative Motion Reproduction for Air to Air Refuelling Simulation

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As computational processing power and actuation technologies improve an increasingly popular technique is that of Hybrid Testing. Hybrid tests involve the testing of physical subassemblies in a real-time simulation, coupled to numerical simulations of complete systems and their related environmental conditions. Sometimes referred to as real time dynamic substructuring, or likened to hardware-in-the-loop testing, they offer the ability to test the performance of components in a highly realistic operating environment while remaining within the low-cost, repeatable, and relatively safe confines of a laboratory. This permits the testing of sensors and systems critical to the safety of equipment and personnel with reduced risk, and facilitates piece-wise management of large projects to mitigate financial risks. The University of Bristol has collaborated with Cobham Mission Equipment to develop a large-scale hybrid test facility for relative motion simulation between two independent bodies. This paper will describe the steps in the development of a facility primarily tasked with replicating an air-to-air refuelling environment (Figure 1). This is a more challenging task since the system dynamics tend to have shorter timescales than those of satellite manoeuvers, and the relative motion is more erratic due to the aerodynamic interactions as well as the unpredictable effects of atmospheric turbulence.

The facility incorporates two six degree-of-freedom articulated robotic arms and a linear rail whose motion may be dictated by real-time numerical simulations of the refuelling environment. This paper will discuss the development of the facility and the different approaches considered for achieving real-time control of the robotic hardware. Data packaging and delay compensation on the network between the real-time platform and the robot controller will also be addressed. It will then go on to focus on aspects of the control topology and motion optimisation which are used to maximise the performance of the facility.

Implementation of the facility in closed-loop simulations of the 'hook-up space' in aerial refuelling is then discussed. The hook-up space is a relatively compact environment with complex interactions between aircraft, refuelling equipment, and aerodynamic effects from the receiver bow wave, wake vortices from the tanker, and air turbulence. A high-fidelity real-time synthetic environment consists of a nonlinear flight dynamic model for the receiver aircraft, along with the dynamics of the probe and trailing para-drogue assembly. A real-time platform handles the control of the robotic arms in synchronisation with data generated

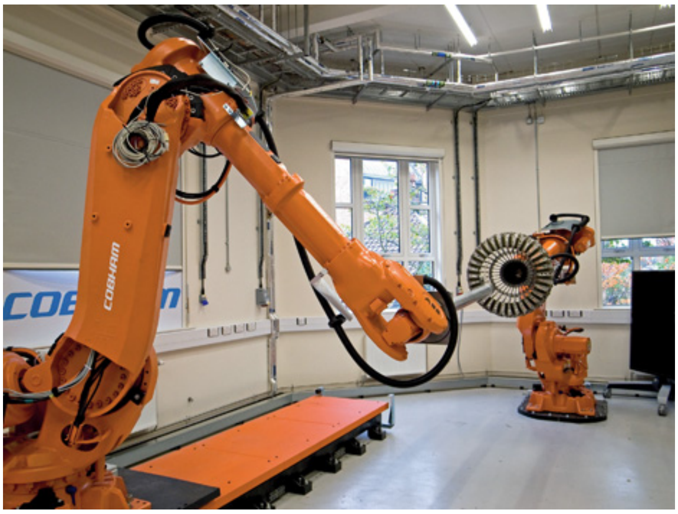

Figure 1: The Relative Motion Robotics (RMR) facility for air to air refuelling simulations

by the simulated dynamics for the refuelling probe and drogue. Data from sensors on robot-mounted equipment are then feed back into the synthetic environment to perform closed loop simulations with real sensors and refuelling hardware. In addition to providing representative data for the robotic test facility the synthetic environment provides a means to test and evaluate a number of different aircraft models, flight control laws, and autonomous behaviour in software-based simulations.