Proceedings of the 2013 Winter Simulation Conference
R. Pasupathy, S.-H. Kim, A. Tolk, R. Hill, and M. E. Kuhl, eds

VALIDATION OF AN AGENT-BASED MODEL OF AIRCRAFT CARRIER FLIGHT DECK OPERATIONS

Jason C. Ryan

Humans and Automation Laboratory
Massachusetts Institute of Technology
Cambridge, MA 02143, USA

ABSTRACT

In this paper we discuss the validation of an agent-based model of aircraft carrier flight deck operations. This model is designed to explore the effects of introducing new unmanned aerial vehicles (UAVs) and related safety protocols into flight deck operations. Validating the system has been challenging, as there is little published information on flight deck operations. Data was assembled from a variety of sources, with the validation process focusing on the simulation's ability to replicate real-world data and that its response to changes in input parameters aligned with observed data and subject matter expert expectations. This poster presents the results of this validation process and discusses features of the simulation that will be added in the future.

1 INTRODUCTION

Currently, there is a push within both military (Office of the Secretary of Defense, 2011) and commercial entities (Rio Tinto, 2011) to introduce unmanned robotic systems into a variety of work domains. In the past, robotic systems have often been completely segregated from human workers in domains such as mining and manufacturing. Currently, research in these areas, among others, is seeking to create collaborative robotic systems that work in the same shared space as humans, manned vehicles, and other robotic systems. In these domains, the safety of individuals within the system, as well as the system itself, is of prime importance. Typically, the safety and productivity of robotic systems are validated by iterative real-world trials. For large-scale systems such as the national airspace system or the national highway network, realistic field trials involving large numbers of vehicles and human workers are difficult to perform. An exploratory simulation tool that replicates these large-scale systems would enable system designers to test various robotic system designs and behaviors prior to requiring their physical implementation in the environment. Such a tool also allows for an exploration of different safety protocols and organizational structures for human workers without placing them in any danger during real world testing.

How to build a simulation that incorporates both human and robotic decision making and physical motion is currently being investigated in the form of the aircraft carrier flight deck. In this environment, upwards of 100 human crewmembers interact closely with up to 60 aircraft. These crew provide manual instructions to taxiing aircraft, while also physically interacting with aircraft to load fuel and weapons. Unmanned vehicles introduced into these environments may have a range of different capabilities due to varying levels of autonomy, affecting their ability to perform tasks and recognize instructions from operators. These changes in autonomous capabilities may also create new failures and new emergent behaviors in the system that may not be apparent to unmanned system designers.

It is unclear at this time how the Navy will adapt to the introduction of UAVs into the flight deck environment. New safety protocols that guide crew behavior may be required in order to keep deck operations at a suitably safe level. The agent-based simulation developed in this research is intended as a testbed to examine how different futuristic unmanned vehicle architectures interact with various possible safety protocols, seeking to understand the tradeoffs between safety (accidents and near-accidents) and productivity (mission execution) in this environment.

2 CURRENT VALIDATION STATUS

The simulation validation process, as discussed in (Law, 2007; Sargent, 2009), and others, requires demonstrating that the simulation is capable of reproducing the performance of the real-world system it is replicating. Validating the carrier simulation has been challenging due to two factors. First, there is little data published on flight deck operations, and what does exist is not directly related to the metrics of interest in this study. Second, validating this agent-based model requires validating both individual agent behavior (e.g., a single aircraft performing a series of tasks) as well as combinations of aircraft (e.g., 20 aircraft simultaneously performing tasks). Successfully validating one does not imply validation of the other.

Validation first focused on replicating individual aircraft missions, based on video data obtained from a variety of sources. Results demonstrate that the simulation environment compares favorably with the empirical data obtained. Tests at the mission level (20 or more aircraft) followed, demonstrating that the system replicates the distribution of launch interarrivals as reported in a series of Navy studies. Sensitivity analyses have shown that the deviations in model performance due to changes in input parameters are reasonable, given the rules that govern traffic and task assignments on the flight deck. At this time, the simulation is considered a valid replication of flight deck operations and will be used as the baseline platform for future upgrades and tests. The iterative process of testing required to reach a valid state revealed several fallacies of the ``simple" rules used to develop the agents and revealed important facets of operations that were not well understood previously.

3 FUTURE WORK

In the near future, the simulation will be upgraded to include additional crew on the flight deck, new unmanned vehicles of various types (teleoperated, semi-autonomous with varying control input modalities, fully autonomous) and safety protocols (temporal segregation of UAVs and aircraft in schedule; physical segregation on deck; variations in collision sensing parameters) to examine the tradeoffs of system design choices in terms of safety and productivity on the flight deck. Implementing these new features is a matter of defining new logical rules that describe unmanned system and crew decision making and movement in the environment. At the conclusion of these additions, the simulation will be exercised to examine various combinations of safety protocols and unmanned vehicle systems, as well as undergo further sensitivity analyses, in order to establish the Pareto optimal tradeoffs of safety and productivity in the system.

4 ACKNOWLEDGEMENTS

This work was performed under the Office of Naval Research Science of Autonomy program, Contract #N000140910625. This work has been supervised by Prof. M. L. Cummings, Associate Professor of Aeronautics and Astronautics and Engineering Systems at the Massachusetts Institute of Technology and Professor in the Mechanical Engineering and Materials Science Department and the Duke Institute for Brain Sciences at Duke University.

Law, A. M. (2007). *Simulation Modeling and Analysis* (4th ed.). Boston: McGraw-Hill.

Office of the Secretary of Defense. (2011). *Unmanned Systems Roadmap 2011-2036*. Washington, D. C.

Rio Tinto. (2011). Mine of the Future. Retrieved from http://www.riotinto.com/ourapproach/17203_mine_of_the_future.asp

Sargent, R. G. (2009). Verification and Validation of Simulation Models. In *2009 Winter Simulation Conference*. Orlando, Florida.