A cognitive game theoretic analysis of conflict alerts in air traffic control

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1. The original motivation:

The current research was motivated by the recommendation made by a joint Government/Industry committee to introduce a new traffic control system, referred to as the Free Flight (see the RTCA report, 1997). This system is designed to use recent new technology to facilitate efficient and safe air transportation. We addressed one of the major difficulties that arise in the design of this and similar multi-agent systems: the adaptive (and slippery) nature of human agents. To facilitate a safe and efficient design of this multi-agent system, designers have to relay on assessments of the expected behavior of the different agents under various scenarios. Whereas the behavior of the computerized agents is predictable, the behavior of the human agents (including air traffic controllers and pilots) is not. Experimental and empirical observations suggest that human agents are likely to adjust their behavior to the design of the system.

To see the difficulty that the adaptive nature of human agents creates assume that a good approximation of the way operators currently behave is available. Given this information an optimal design can be performed. The problem arises as the human operator will learn to adjust their behavior to the new system. Following this adjustment process the assumptions made by the designer concerning the operators behavior will no longer be accurate and the system might reach a suboptimal state.

In extreme situations these potential suboptimal states might involve unnecessary risk. That is, the fact that operators learn in an adaptive fashion does not imply that the system will become safer as they gain experience. At least in the context of Safety dilemmas (Erev, Gopher, Itkin & Greenshpan, 1995; Erev & Gopher, 1999), experience can lead to a pareto deficient risk taking behavior.

2. The main results

The current project focused on two distinct (and complementary) approaches to address the adaptive nature of human behavior. The first, and the more ambitious one, involves the development of a descriptive model of the way human agents adjust to new incentive systems in air traffic control tasks. A second study examines the effects of the design of simulators on their ability to predict the outcome of social interactions.

2.1 Modeling learning in air traffic control tasks

Our analysis suggests that most important air traffic control decisions involve a "detection of change" tasks. That is, the decision makers (air traffic controllers and pilots) have to detect a change in the environment (the emergence of a risky situation that requires an action). Based on this suggestion (working assumption) our first study focused on modeling learning in detection of change tasks. The study (first draft of the paper attached) started by reviewing the relevant theoretical and experimental literature. The review reveals that optimal decision in this setting requires complex computations (see analysis in Rapoport, Stein & Burkheimer, 1979), and human agents fail to behave optimally. The robust violations of the optimal model (observed by Barry & Pitz, 1979, and Shtraucher, 1979) include a status quo bias (a tendency to response too late), a probabilistic response rule and slow adjustment process.

The second section in the paper presents a replication of the early studies in a simulated air traffic control setting. This study replicates the main trend observed in the published studies and includes additional data that facilitate evaluation of learning.

The third part of the paper use these data to propose a model (a generalization of the model proposed by Erev, 1998) that can capture the main results.

The forth and final part of this research presents a second experiment that was design to test the predictive value of the proposed model.

2.2 Simulators and social interactions

The common approach to the prediction of human adaptation involves the utilization of simulators. This approach requires the development of a simulator of the environment under interest, and examination of human behavior in these simulators in controlled experiment. Whereas this approach appears to require "shallower understanding" of human behavior (relative to the attempt to develop a quantitative learning model), some understanding is required to insure that the simulator simulates the important aspects of the environment.

The current study addresses the difficulties that arise in an attempt to simulate multi agent systems. Previous studies of multi agent interaction (see review in Dawes, 1980) reveal a strong effect to the group size. Whereas dyads typically appear to reach efficient outcomes (e.g., cooperation), larger groups tend to converge to inefficient equilibrium. Thus, attempts to simulate multi agent interactions, like the Free Flight environment in small simulators (i.e. simulators in which only two simulated jets can interact) might lead to biased conclusions.

A possible solution to this difficulty is suggested by the finding that a group is becoming "large" very fast. Cooperation was observed in dyads, but not in larger groups. Thus, it is possible that simulators with four simulated jets may be large enough. To evaluate this optimistic assertion the current research examines a simulation of a well understood traffic problem (for which the common behavior in a multi agent interaction is well known). And asks how large should be the group size (number of cars in our simulator) to obtain the behavior observed in the natural multi agent setting. Early results (we hope to complete this study in few months) support the optimistic hypothesis: Whereas, a simulator of size two yield biased results, a simulator of size four captures the natural behavior.

3. Final drafts

We expect to finish the two papers this year. Thus, in addition to this final report we will submit final drafts of the papers to NASA.

References

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