Abstract for 2011 CPS PI Meeting (Collaborative Research):
Distributed Coordination of Agents For Air Traffic Flow Management

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Abstract : This project addresses the management of the air traffic system, a cyber-physical system where the need for a tight connection between the computational algorithms and the physical system is critical to safe, reliable and efficient performance. Indeed, the lack of this tight connection is one of the reasons current systems are overwhelmed by the ever increasing traffic and suffer when there is any deviation from the expected (e.g., changing weather). Multiagent coordination algorithms are ideally suited to address this problem, though the interactions among the agents need to be implicitly taken into account since the complex domain cannot be accurately modeled fully. In this project, we study the impact of agent rewards and interactions on system performance using data from real air traffic systems. The objectives of this project are to:

1. Derive reward estimation to augment a new event-based air traffic simulator;
2. Analyze the impact of modifying agent actions and rewards; and,
3. Demonstrate the effectiveness of selecting agents' actions and rewards with real air traffic data obtained from historical congestion scenarios.

The intellectual merit of this project lies in its addressing the agent coordination problem in a physical setting by shifting the focus from "how to learn" to "what to learn." By exploring agent reward functions that implicitly model agent interactions based on feedback from the real world, we are building cyber-physical systems where an agent that learns to optimize its own reward leads to the optimization of the system objective function.

The broader Impact of this proposal is in providing new air traffic flow management algorithms that will significantly reduce air traffic congestion. The potential impact can not only be measured in currency ($41B loss in 2007) but in terms of improved experience by all travelers, providing a significant benefit to society.

Progress to date (July 2011) has been significant with second year activities directly supporting all three objectives. (i) The Fast, Event-based Air Traffic Simulator (FEATS) is fully functioning and providing a testbed for all agent based algorithm testing: (ii) Our results show reduced congestion if agents control traffic flow at fixes using the derived reward functions in 15-20 airport simulations with artificial data. (iii) Our earlier results had shown to be effective in realistic air traffic scenarios with up to eighteen hundred aircraft over the course of a day, which amounts to regional air flow. By using reward estimation and reward modification, we extended our methods to optimize air traffic flow in the entire US airspace, comprising of more than six thousand aircraft over the course of an hour.

The combined effort on all three fronts show that with a reasonable amount of computation load, the entire US airspace can be simulated and managed with significant performance gains. The findings are encouraging as they show that both the reward estimation and the reward shaping methods significantly improve our optimization capability when using real-world air traffic data for the full US airspace. In addition our results are obtained while keeping the full flexibility of our distributed agent architecture, allowing these techniques to be used on variations of real-world scenarios with increased complexity. These methods will prove critical for both regional and global optimization of air traffic flow.