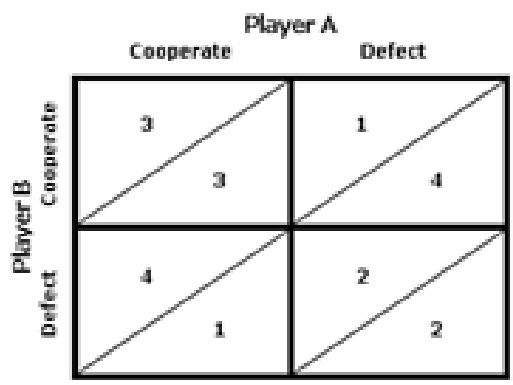
Intelligent Data Understanding's Probability Collectives for Science and Engineering

The Ames Intelligent Data Understanding Group uses Probability Collectives to support the fields of Science & Engineering.

Background

The Intelligent Data Understanding (IDU) Group has uncovered the shared mathematical structure (Probability Collectives) that unites the three sciences related to multi-agent systems: game theory, statistical physics, and control theory. We are applying Probability Collectives to adaptive, distributed control. We use separate agents to set all control variables such that the global control objective is optimized. Our objectives include: minimizing the communication required between agents, ability to handle multiple objectives, robustness of the solution, and adaptive response to an unknown environment.



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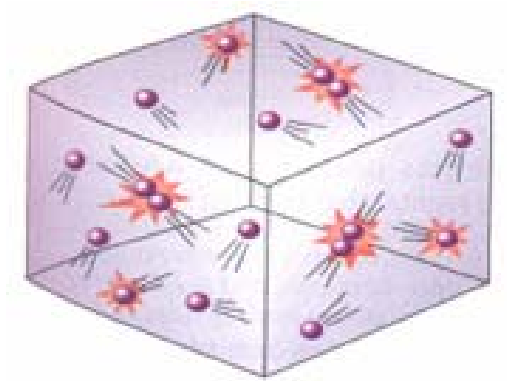

Research Overview

We recently proved that game theory and statistical physics are identical when cast in terms of information theory.

We call the associated formalism Probability Collectives (PC). PC opens many new lines of research, and provides new approaches to problems in distributed control and distributed optimization.

Intuitively, players in a game and their reward functions are mathematically identical to particles in a system and their energy functions. Games with varying numbers of agents are analogous to physical systems with varying numbers of particles. Quantified bounded rationality of agents is formally identical to the temperature of particles.

This deep identity opens a hybrid field where the techniques of game theory and statistical physics can be combined and exploited (e.g., for discrete, continuous, mixed, and constrained optimization).

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A NEW STATE OF THE ART
Collaborators at Ames, Oxford, Stanford, Berkeley, Los Alamos, GE, and BAE Systems have been investigating the extremely rich theory arising from this hybridization, with applications in areas such as distributed optimization and control of multi-agent systems.

Algorithms developed to date have always far outperformed conventional techniques in simulation, and this performance has been verified in a few hardware demonstrations. The techniques also are adaptive, robust, and fault tolerant. They also scale well, giving increasing benefits as system size grows.

In these algorithms, agents in the "collective" strive for a global objective -- perhaps multiple simultaneous objectives -- by pursuing their own best interests. Previously, designing individual (or "local") control laws to achieve this has been difficult.

The PC Golden Rule:

**Instead of finding *x*
to optimize a function,
find a distribution over *x*
that optimizes an associated
expectation value.**

(This transforms optimization problems over discrete or hybrid domains to problems over continuous domains.)

APPLICATIONS
The PC approach is widely applicable, with minimal (or even no) hand-tuning. Potential applications include:
•Flaplet arrays to stabilize aircraft wings.
•Design of other aircraft structures and systems.
•Adaptive programming of nanocomputers.
•Airline fleet assignment.
•Investment and computational economics.
•Population biology studies.
•Coordination of human teams.
•Control of UAV clusters or agent teams.
•Control of robots for space station construction.
•Multi-disciplinary Optimization
•Telecommunications Routing
•and more...

Using PC, independent flaplets stabilize a wing at high speeds.

Relevance to Science & Exploration Systems Mission Directorates

Probability Collectives developed by the Intelligent Data Understanding Group will enable scientists & engineers to better answer important questions in their fields. Methods developed can maximize project results while minimizing costs.

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