Multi-agent Group Decision Making

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Overview

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Introduction

- Realising effective multi-agent systems requires cooperation and coordination between agents
- We are interested in cooperation in *open environments:*
  - agents are neither centrally owned nor controlled
  - agents may enter/leave a system at will
  - E.g. the Internet
- We wish to determine what actions agents should perform:
  - “What should the agents do?”
- We have looked to nature for inspiration

Problem Statement

- For a group of individuals, each having a preference over their possible actions, attempt to determine an allocation of one action to each individual satisfying:
  - **feasibility**; individuals are allocated actions they are able to perform,
  - **individual rationality**; no individual would prefer to leave the group rather than perform their allocated action
  - **consistency**; no individual is allocated an action which is inconsistent with the actions of others

Problem Formalisation - 1

The tuple $\langle G, A, S_1, ..., S_n, \succ_1, ..., \succ_n, C \rangle$ where:

- G is a set of agents, $\{1, \ldots, \mathrm{n}\}, \mathrm{n} \geq 2$
- A is a set of possible actions, $\{a_1, ..., a_m\}$
- $S_i \subseteq A$ is a set of feasible actions for each agent
- Action a_j is feasible for $i \in G$ if $a_j \in S_i$
- Joint action $a = \langle a_k^g, ..., a_l^h \rangle$ is feasible for agents $\{g, ..., h\}$ if each action is feasible for each agent
- $\succ_i$ is a total order over S_i

Problem Formalisation - 2

- $C \subseteq \bigcup_{G' \in \wp(G)} \prod_{i \in G'} S_i$ is a set of consistency constraints
- Joint action $\left\langle a_k^g, ..., a_l^h \right\rangle \in C$ may be consistently performed by agents $\{g, ..., h\}$
- The joint action $a = \left\langle a_k^g, ..., a_l^h \right\rangle$ by the group of agents $G' = \{g, ..., h\}$ is a *consensus action* if there is no consistent and feasible joint action a' for some group $G'' \subset G'$ such that all agents in G'' prefer a' to a

Collective Action: Research Context

- Related work includes:
  - SharedPlans [Grosz & Sinder, 1990]
  - Joint Intentions [Cohen & Levesque, 1991]
  - STEAM [Tambe, 1997]
- These works have not considered:
  - open environments
  - the explicit preferences of agents
  - group decision mechanisms other than instantaneous unanimity

Group Decision Making in Nature

- Decisions faced by animal groups include:
  - Direction of travel
  - Timing of departure
  - Location of e.g. nesting sites
- Failure to reach consensus leads to group fission
  - an outcome which is often undesirable

Drawing Inspiration From Nature

- In nature decision makers are:
  - heterogeneous:
    - Abilities
    - ‘Beliefs’
    - ‘Desires’
    - ‘Intentions’
  - non-omniscient
  - transient
- These properties are analogous to agents within open systems

Quorum Sensing & Response [QSR]

- Quorum sensing – determining the number of conspecifics committed to some choice
  - Exhibited by bacteria, eusocial insects and fish
- Quorum response:
  - The probability of some individual making a given choice is increasing in the proportion of individuals already having made that choice
  - This probability increases sharply once some threshold is met

Useful Properties of QSR

- Information pooling
  - Greater accuracy in comparison to the decisions of individuals
- Speed/accuracy trade-off
  - High thresholds -> accurate outcomes
  - Low thresholds -> speedy decisions
- Group cohesion
  - The quorum response is thought to discourage group fission events

Future Work

- Natural models of QSR assume individuals follow identical responses
  - We are interested in circumstances where this assumption is relaxed – Individually Oriented QSR
- Characterisation of IO-QSR, for example:
  - Necessary/sufficient conditions for consensus
  - Adherence to Arrovian characteristics
  - Adherence to Condorcian characteristics

Summary

- Collective action selection can be represented as a social choice problem
- Natural systems share many properties with open multi-agent systems
- Many natural systems employ QSR as the group decision mechanism
- QSR seems a promising approach to multi-agent group decision making

Thanks for listening

- For further information
  - Contact: jxz@cs.nott.ac.uk
- Perhaps there are some questions?