Challenges of Information Sharing in MMAS

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Managing information is the key to effective Massive Teams

If the team has a shared understanding of the situation and how to deal with it, local decision-making is relatively easier
Research Questions

• When many heterogeneous agents are sharing uncertain information on a network, what dynamics will occur?
  - What factors impact dynamics?
  - What emergent behavior occurs?

○ What will be the convergence properties?
"Double Counting" Problem

Sensor

\[ p(x) = 0.7 \]

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\[ p(x) = ? \]
"Double Counting" Problem

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Dominating Dynamic Phenomenon: Cascades

- A single sensor reading (or simultaneous set of readings) can cause many agents to simultaneously change state
  
  - e.g., Unknown to true
  
  Referred to as an cascade

- Cascades vary in size
Distribution of Cascade Sizes

![Graph showing the distribution of avalanche sizes. The x-axis represents avalanche size, ranging from 1 to 10,000, and the y-axis represents avalanche frequency, ranging from 1 to 10,000,000. The graph displays a power-law distribution with a sharp drop-off at larger avalanche sizes.]
Convergence

X-axis: Number of agents reaching correct conclusion

Y-axis: Number of simulations out of 2500 when number occurred

Bifurcation

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System Dynamics

\[ P(c) \propto c^{-3/2} \exp \left( - \frac{\omega c}{(1 - \alpha)^{-2}} \right) \]

- Probability of cascade of size \( c \)
- Constant
- Branching factor

Note that given the preceding definitions, we discretize the belief range between the observations conflicting with its belief that an agent would need for range. For a fixed value of \( n \), we define the belief range of possible belief ranges that a neighbor could be in. We discretize belief and communicates with its neighbors. This is expressed by Equations which relate the system parameters to the probability of an avalanche encompassing the range at time \( t = 0 \). Functions for both true and false beliefs are given by solving the system of difference equations which express the change in beliefs at time \( t = 2 \) (1, ..., \( n \)). The number of agents that enter from this belief range from the time \( i \) is given by the equations which give the relationship between the number of agents whose belief enters the avalanche \( z \) having a belief in each range: There is one non-trivial fixed point: α is a function of parameters \( t \) and \( i \).
Three Qualitatively Different Behaviors

Low “trust” in neighbors

\( \alpha < 1 \)

High “trust” in neighbors

\( \alpha > 1 \)

Scale Invariant Dynamics

\[ P(c) \propto c^{-3/2} \]

Cascades
Scale Invariant Dynamics

Convergence time

Reliability

"Trust"
Variation with Network Type and Density

Scale Free

Random

Small World Grid

Small World Ring

Grid

Hierarchy

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Within Type Variation

![Bar chart showing variation in SF Network Instances](chart.png)
Local Controller

- Network details change scale-invariant range in complex ways
- Very difficult to analytically predict
- Iteratively move the local “trust” based on local estimate of branching factor
- Moves system very close to optimal performance
Results

Reliability

Network Type

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Effective use of information is key to scaling up teamwork to massive teams

Fundamentally different challenges to smaller teams

Important effects might be system-wide “emergent” dynamics