Majority-rule opinion dynamics with differential latency

Will Vining

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Outline

Basic Model

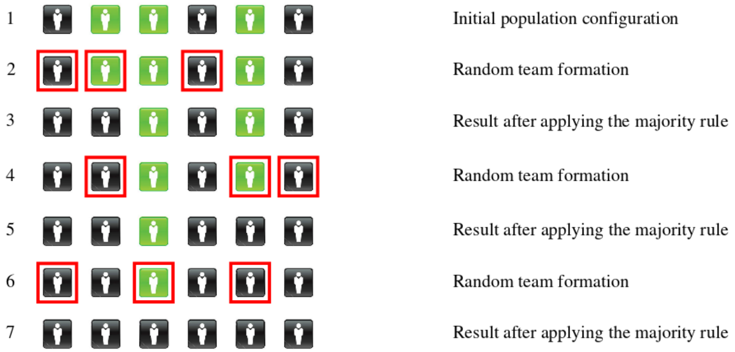


Figure: The basic majority rule model

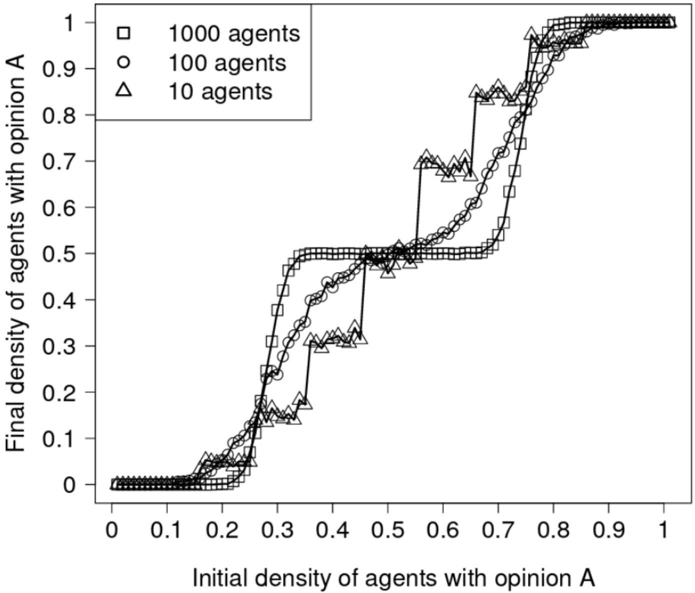
Dynamics

- The model will converge to the majority opinion
- As the number of agents increases the probability of converging to the original majority opinion increases for smaller and smaller majorities.

Model with latency

- After changing state, agents become *latent*.
  - Latent agents can influence the opinion of others, but cannot change their opinion (ie. can't be influenced)
- Each time a latent agent is selected to be part of a team, the agent becomes non-latent with probability λ
- For some λ it is possible for the proportion of agents favoring a particular opinion to fluctuate randomly, and never converge.
  - called "zero magnetization"

Dynamics with latency ($\lambda = 1/20$)



Motivation

- A swarm of robots may need to select some action to take
- It may be desirable for all robots to select the same swarm
- Bound the probability that the robots will converge to a particular opinion given some environmental conditions
- Motivating examples
  - Use search algorithm A or algorithm B
  - Do or do not use task partitioning

Model

The extended model is influenced by the embodied nature of robots

- Latency is directly mapped to the time taken for a robot to perform an action.
- Latent agents are excluded during team formation
  - this means that they cannot be influenced by or *influence* the opinions of other agents.
- Agents always go in to a latent state when their team makes a decision (since they go perform an action).

Exponential distribution dynamics

- the dynamics can be modeled as a system of differential equations,
  - one for the fraction of agents with opinion A
  - one for the number of agents with opinion A

$$\dot{f} = -rp + a \tag{1}$$

$$\dot{a} = -a + r(3p^2 - 2p^3)$$

Figure: Dynamics of the system with exponentially distributed latency

Opinion dependent latency

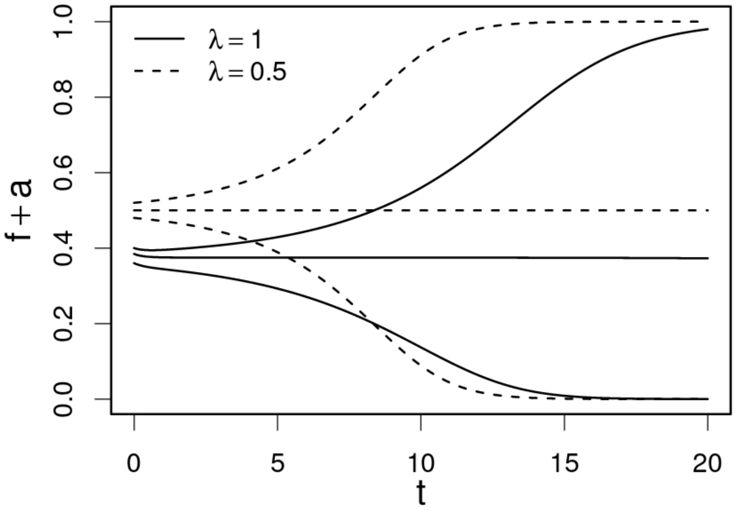


Figure: Despite starting as the minority opinion, because A has lower latnecy the population converges to opinion A (top solid line)

Exponentially distributed latency

- the model is analyzed as a system of differential equations
- It is shown that under exponentially distributed latency periods, agents will always reach consensus.
- It is possible that the consensus may be the opinion that was the in the minority initially, if the alternative opinion has longer latency.

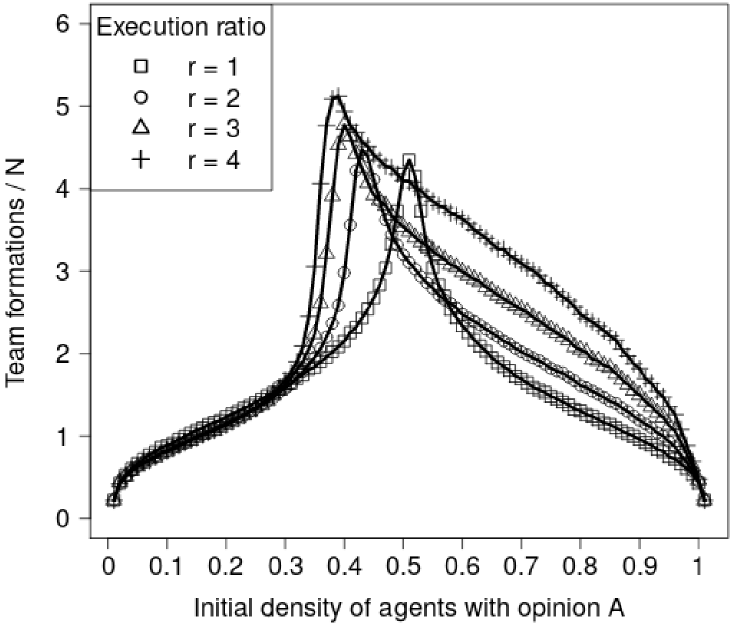
Normally distributed latency

- The latency for each opinion is normally distributed mean/std. deviation for each opinion.
- The model with normally distributed latency periods is analyzed using a Monte Carlo simulation.

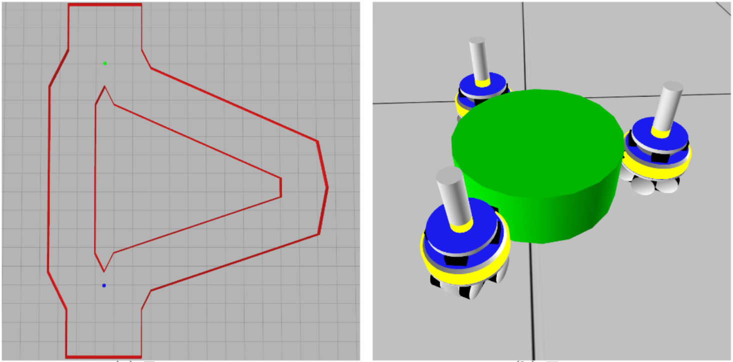
Normal distribution results

- It is more likely that consensus will be on the opinion having the lowest mean latency. (Figure 6(c,e))
- Increasing the number of teams generally increases the likelihood of reaching consensus on the opinion with shortest latency.
- The overlap between mean latency effects the probability that agents will reach a consensus.
  - In general the system will reach a consensus regardless of the amount of overlap between the latency distributions

Number of team formations



Robot experiment



(a) Environment (b) Team

Figure: Collective transport with two alternative paths

- video

Experiment Results

- Robots reach a consensus on the shorter path
- not perfect due to collisions forcing some robots to take the longer path on the return trip

Benefits to this approach

- Can be accomplished using only local sensing/communication.
- Can be thought of as roughly equivalent to pheromones,
  - but simpler to implement in real life
- Does not rely on measurement of distances or time, latency periods are implicitly measured by the rate at which agents become non-latent.
- Decision making is a continuous process; however, after a consensus has been reached decision making stops
  - cannot adapt to a changing environment.

Conclusion

- May be time to depart from biological inspiration.
- At the very least there are many effective algorithms to be discovered from an engineering point of view.