Startle Response Changes Collective Behavior

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Introduction

Autonomous entities exhibiting self organization and group formation within a large collection are ubiquitous in nature. These collective behaviors have been modeled to reproduce motions of animal groups and investigate the spatial dynamics of such systems; Levine and Rappel have demonstrated vortex behavior with equations that depend exponentially upon spatial separation.

However, the spatial dynamic models do not account for changes within the formation caused by responses to internal and external stimuli. Recently Marras et al. studied the effect of a startle stimulus and characterized the corresponding escape maneuvers. The propagation of a startle stimulus has also been modeled probabilistically.

Objective

•Couple Levine and Rappel's exponential model of spatial dynamics with a probabilistic model for startle response

•Investigate the qualitative changes a startle stimulus has on a vortical formation and on propagation of stimulus detection

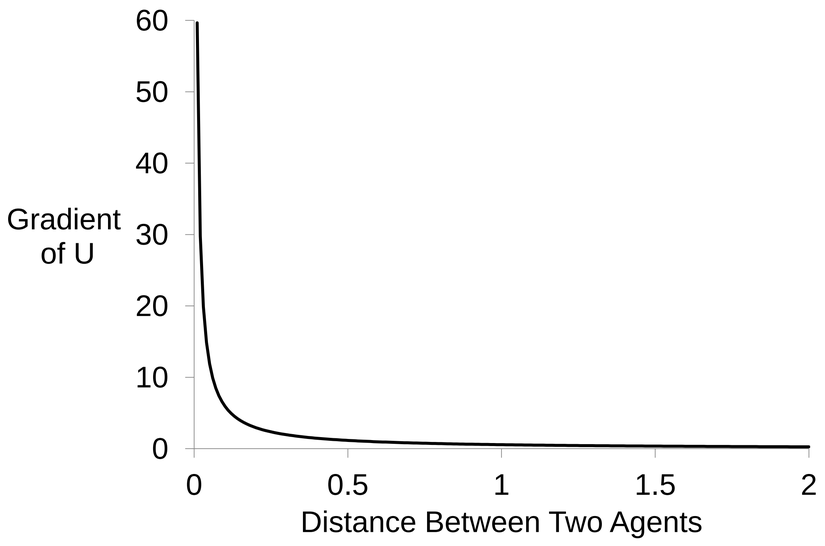
Method

Levine and Rappel's Governing Equation for Each Agent *i* in Group *N*

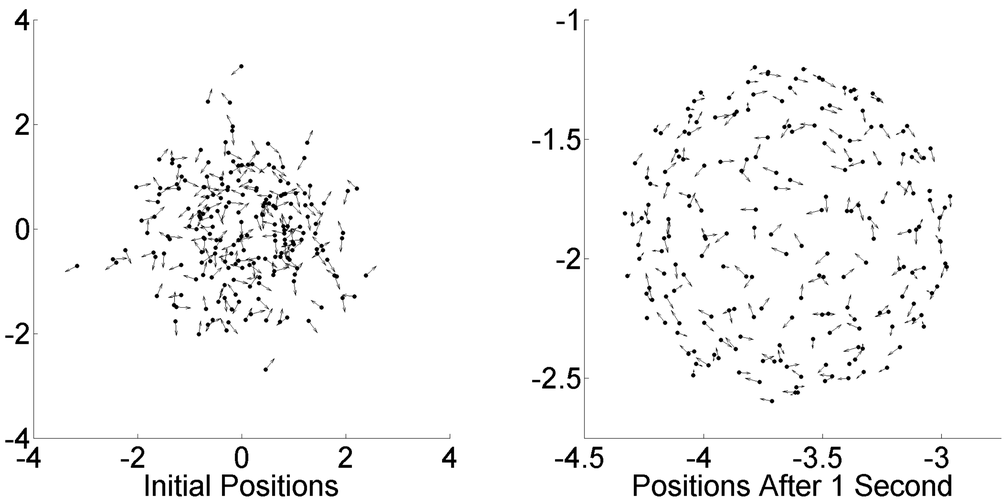
$$m_i \partial_t \vec{v}_i = \alpha \hat{f}_i - \beta \vec{v}_i - \vec{\nabla} U$$

- ***m*** is the mass of each agent
- ***v*** is the velocity, the derivative of position
- ***f*** is the self-propelling force of magnitude **α**
- **β** is the friction coefficient
- ***U*** is a exponential decaying spatial interaction summed over all agents.

The Gradient of *U* for the Interaction Between Two Agents.



Formation for a Group of *N* =200



- Shape of formation is consistent over parameter space
- Agents tend to align themselves directionally after several seconds
- Stable over long periods of time

Startle Response

- Large instantaneous change in speed and direction

Let $P_i(t)$ be the probability that each agent *i* detects and responds to a startle stimulus at time *t*

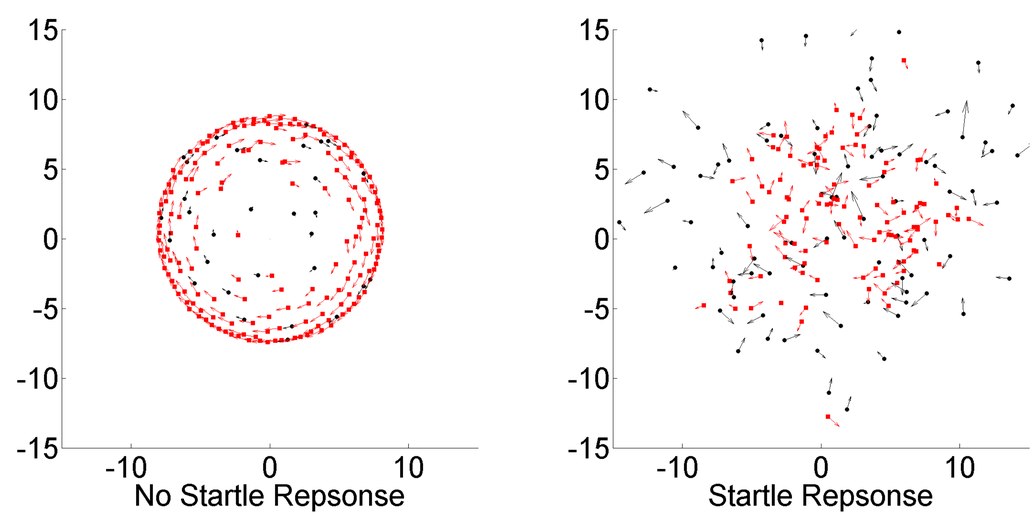
$$P_i(t) = 1 - (1 - P^{(far)})(1 - P^{(sus)} P_i(t-1))$$

$$\prod_{j \in N_i(t)} (1 - P^{(int)} P_j(t-1))$$

- $P^{(far)}$ is the probability of a false alarm
- $P^{(sus)}$ is the probability of sustaining a response
- $P^{(int)}$ is the probability of transmission between two agents that decays exponentially by separation.

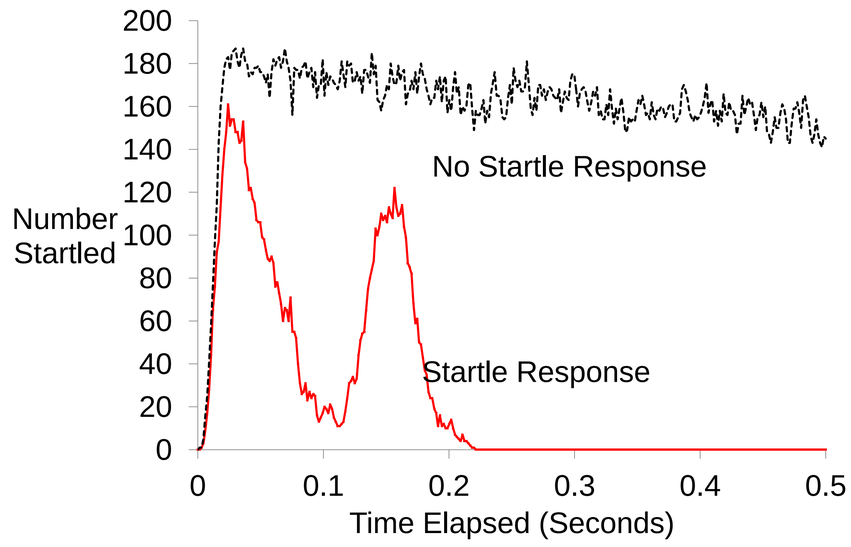
Results

Differences in Formation and Propagation After 0.15 Seconds



- Red squares signify startled agents.
- Starting with developed vortex and one startled agent

Comparing the Number of Agents Startled Over Time



Conclusion and Future Work

A startle response will cause a stable vortex formation to break down as the startle is propagated. On the other hand, the startle is maintained longer among agents who do not exhibit the startle response behavior. This is caused by the continued proximity of the agents with respect to one another.

Further research could focus on the parameters of the startle response to model formations that can transition between stable states and more realistically represent organisms in nature. Work could also be done to explore other stimulus transmissions that evoke different escape maneuvers. The mechanisms of stimulus propagation could be studied to provide more accurate values for the probabilistic model.

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