

Robust and self-repairing formation control for swarms of mobile agents

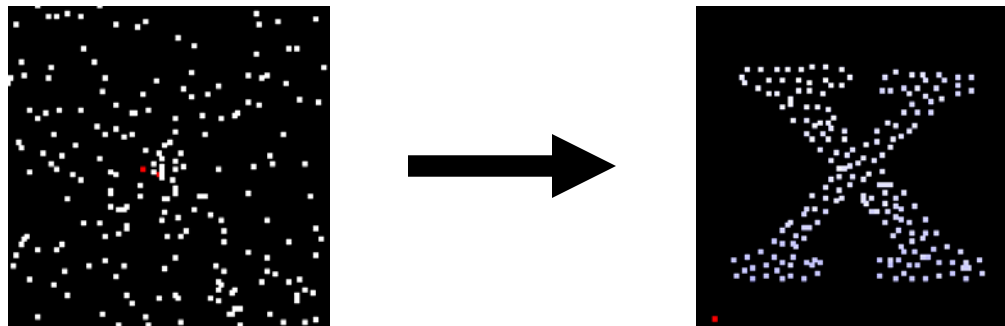
Jimming Cheng
Harvard University

Winston Cheng
Harvard University

Radhika Nagpal
Harvard University

Swarm formation control

*Program a mobile swarm to **robustly self-aggregate...**
into **arbitrary formations...**
with **no global supervision.***



Applications

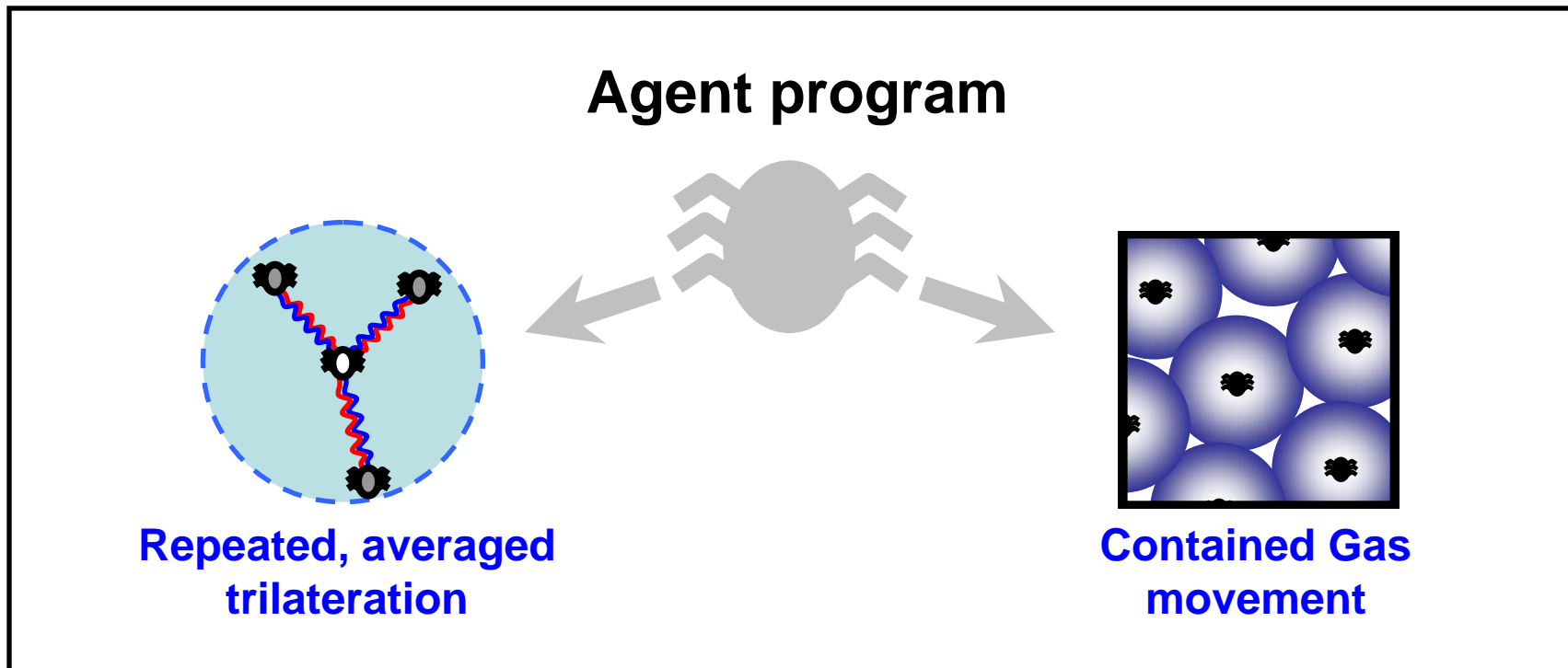
- Set up sensor network layout
- Explore/map unknown terrains
- Maintain formations for defense or herding

Objectives

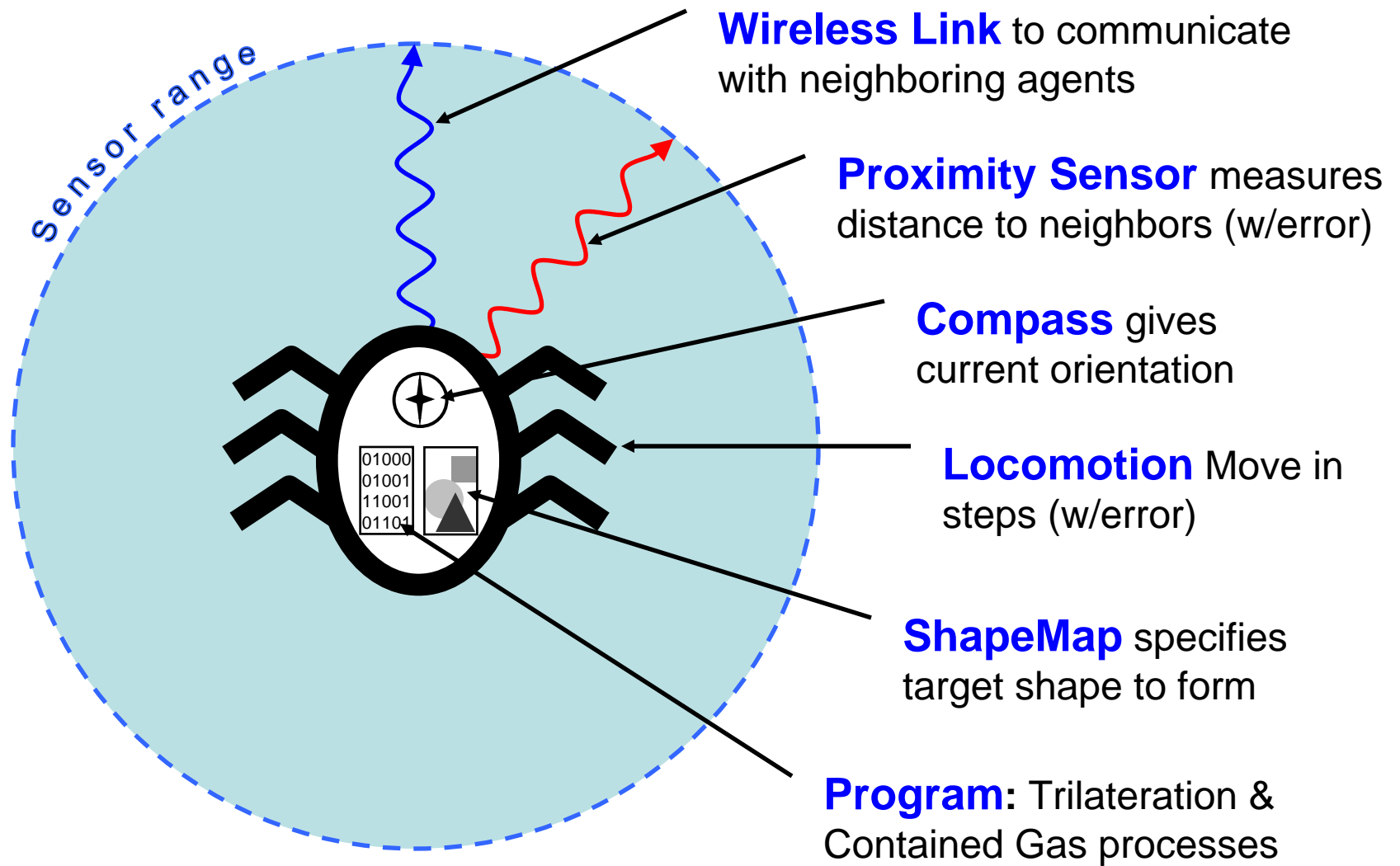
- Decentralized algorithm
 - Resists individual failures
- Easily form arbitrary shapes
 - Simple, flexible shape specification
- Robustness
 - Self-repair for agent death
 - Recover from mutilation

Our approach: Shapebugs

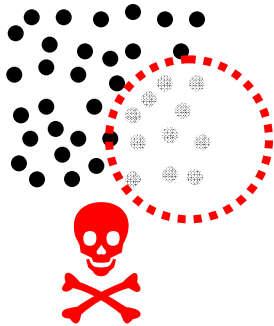
1. Shape described as digital bitmap (ShapeMap)
2. Negotiate **consensus coordinate system**
3. Distribute within shape boundaries



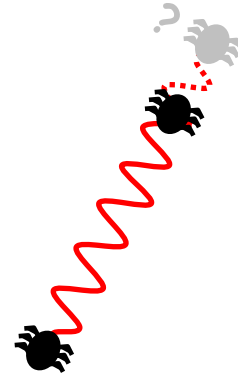
Agent model



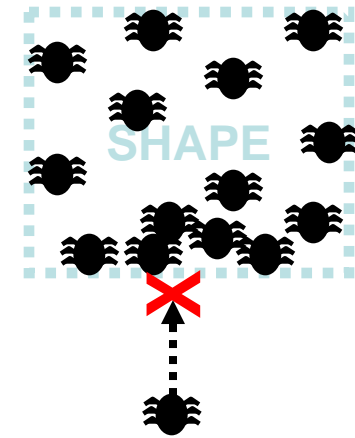
Challenges



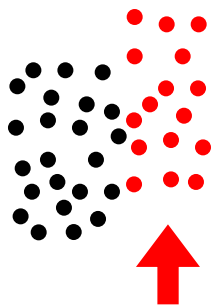
Agent death



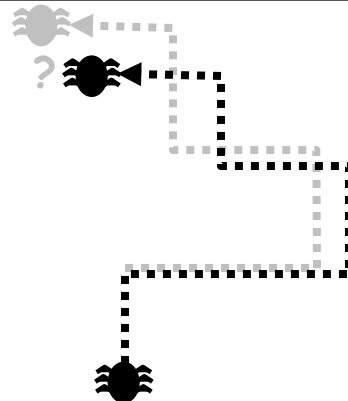
Proximity sensor noise



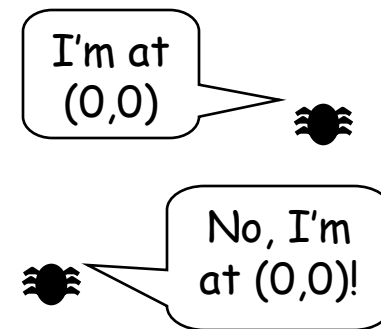
Blocking/traffic jams



Shape mutilation



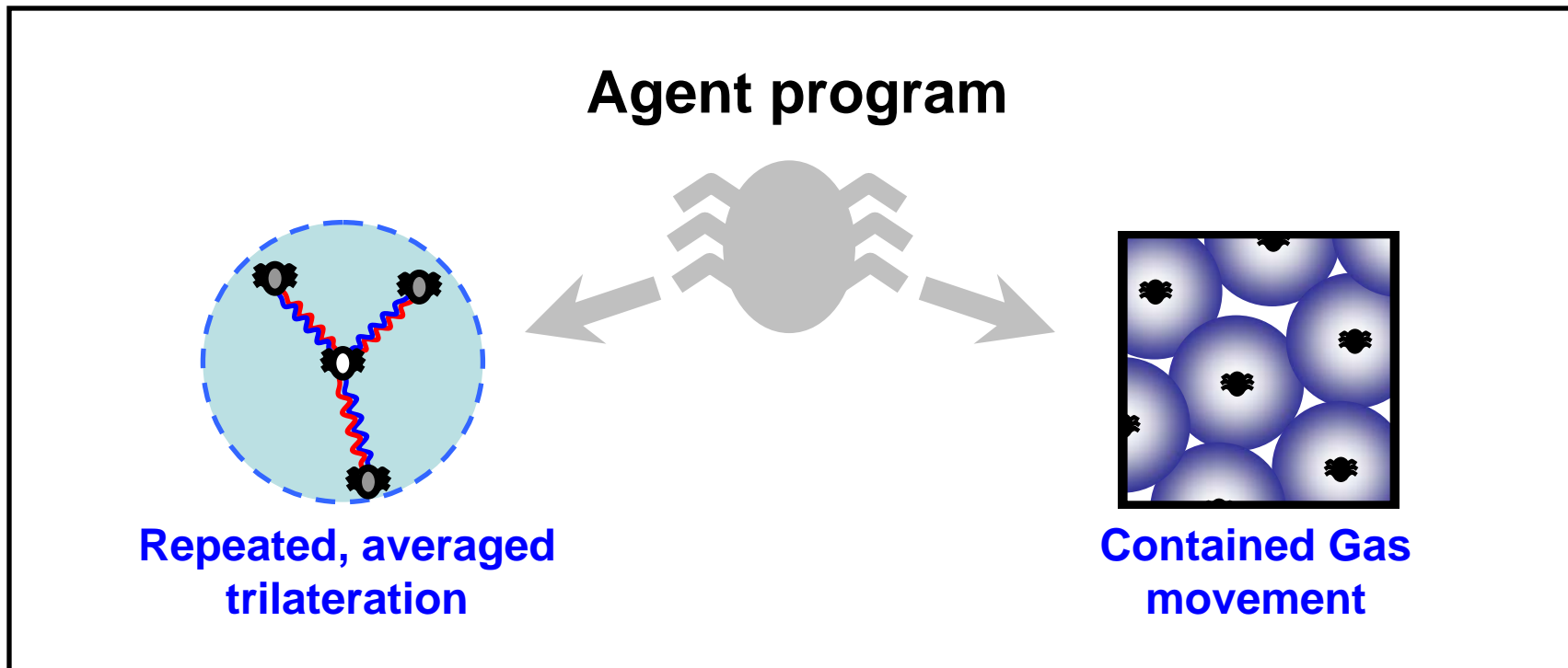
Movement error accumulation



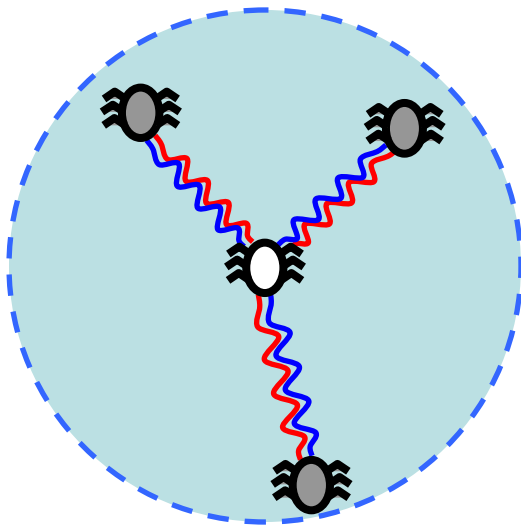
Coordinate system conflicts

Our approach: Shapebugs

1. Shape described as 2D bitmap
2. Negotiate **consensus coordinate system**
3. Distribute within shape boundaries



Process 1: Repeated, averaged trilateration

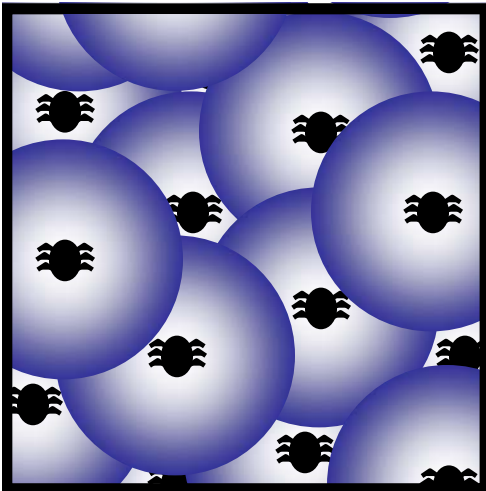
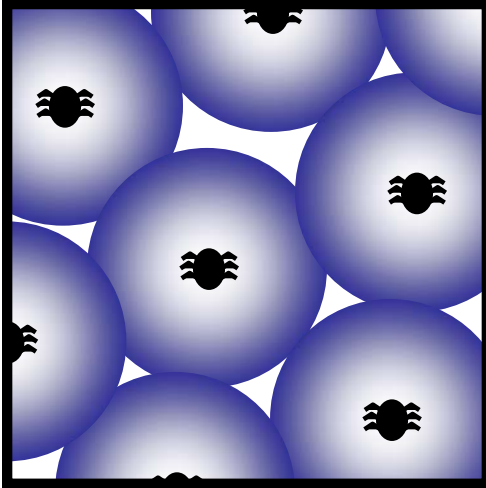


Infer consensus coordinate system with **trilateration**, using:

1. Proximity to each neighbor
2. Position reported by each neighbor

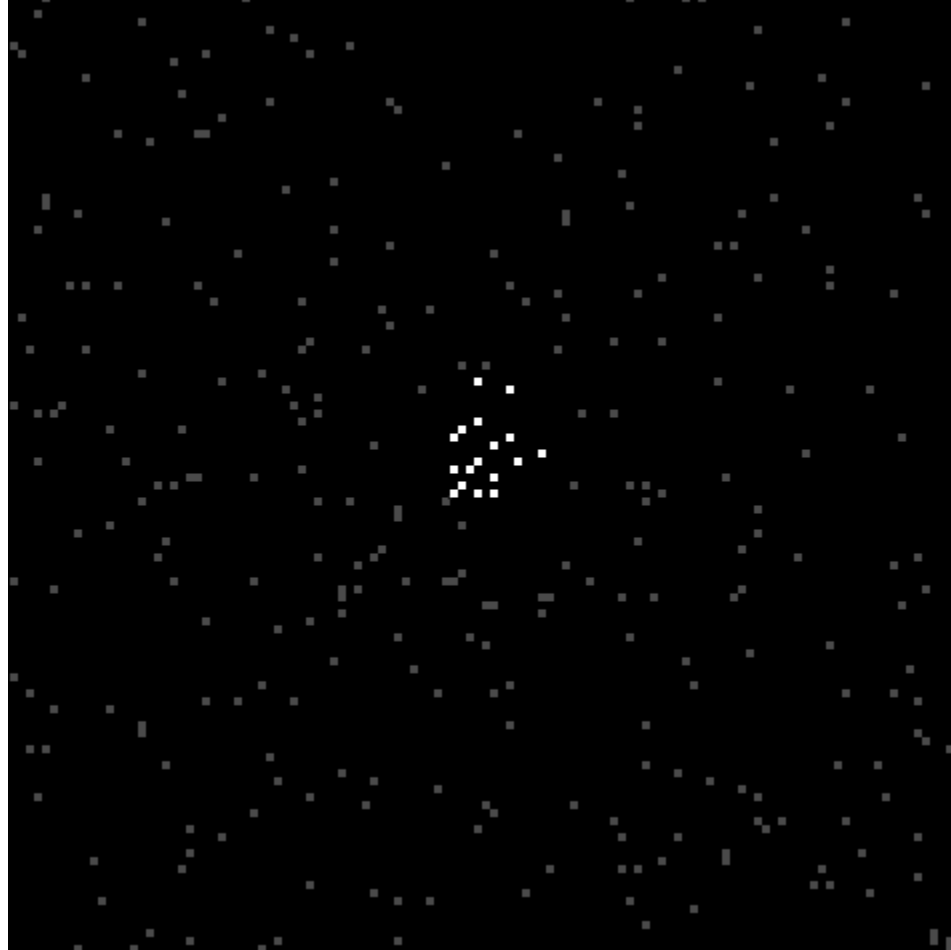
Repeated trilateration reduces movement error buildup
Averaged trilateration filters out proximity sensor noise

Process 2: Contained Gas movement

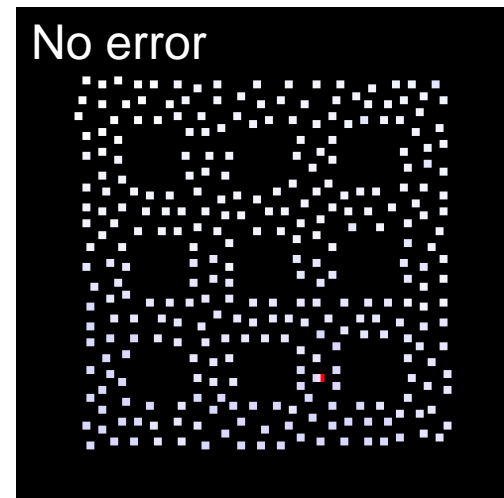
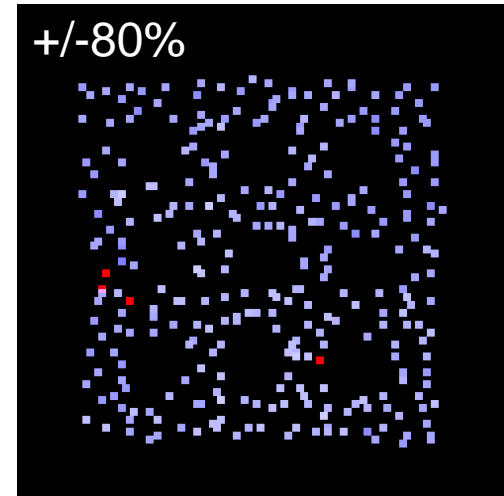
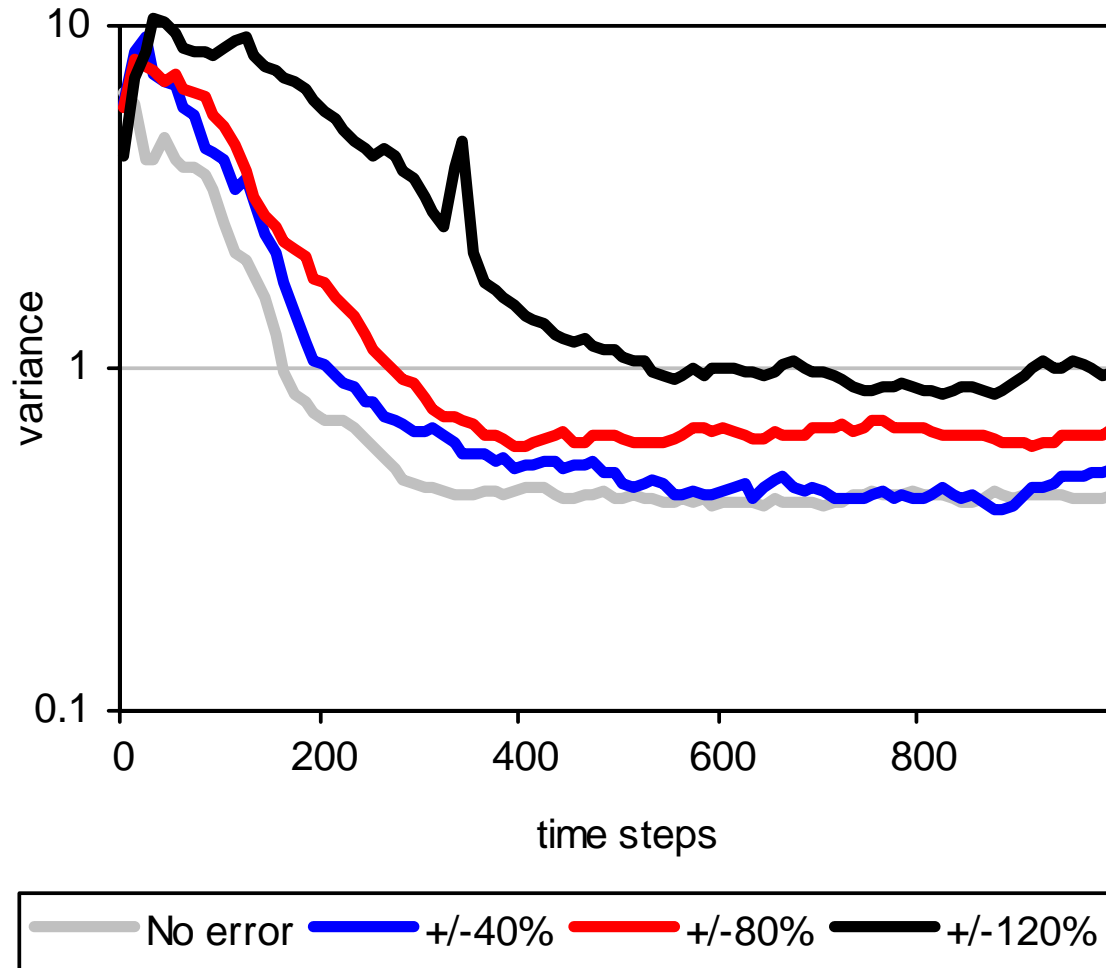


- Agents repulse each other with decaying strength: *S – proximity*
 - Agents distribute evenly at any density
 - Disperses blocking problem
 - Self-repair by filling voids
 - Improves trilateration
- Agents avoid moving out of shape boundaries

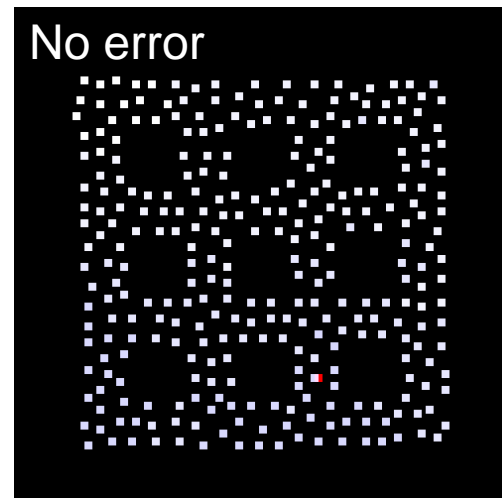
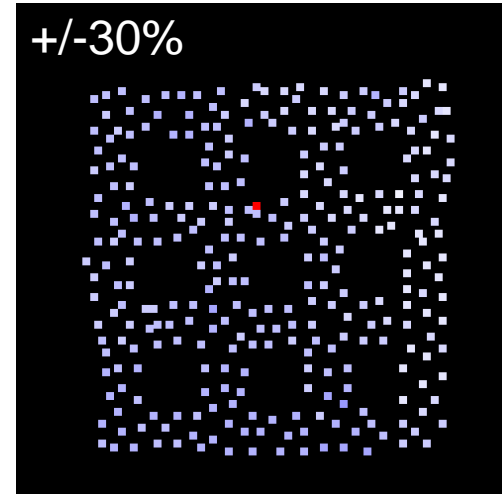
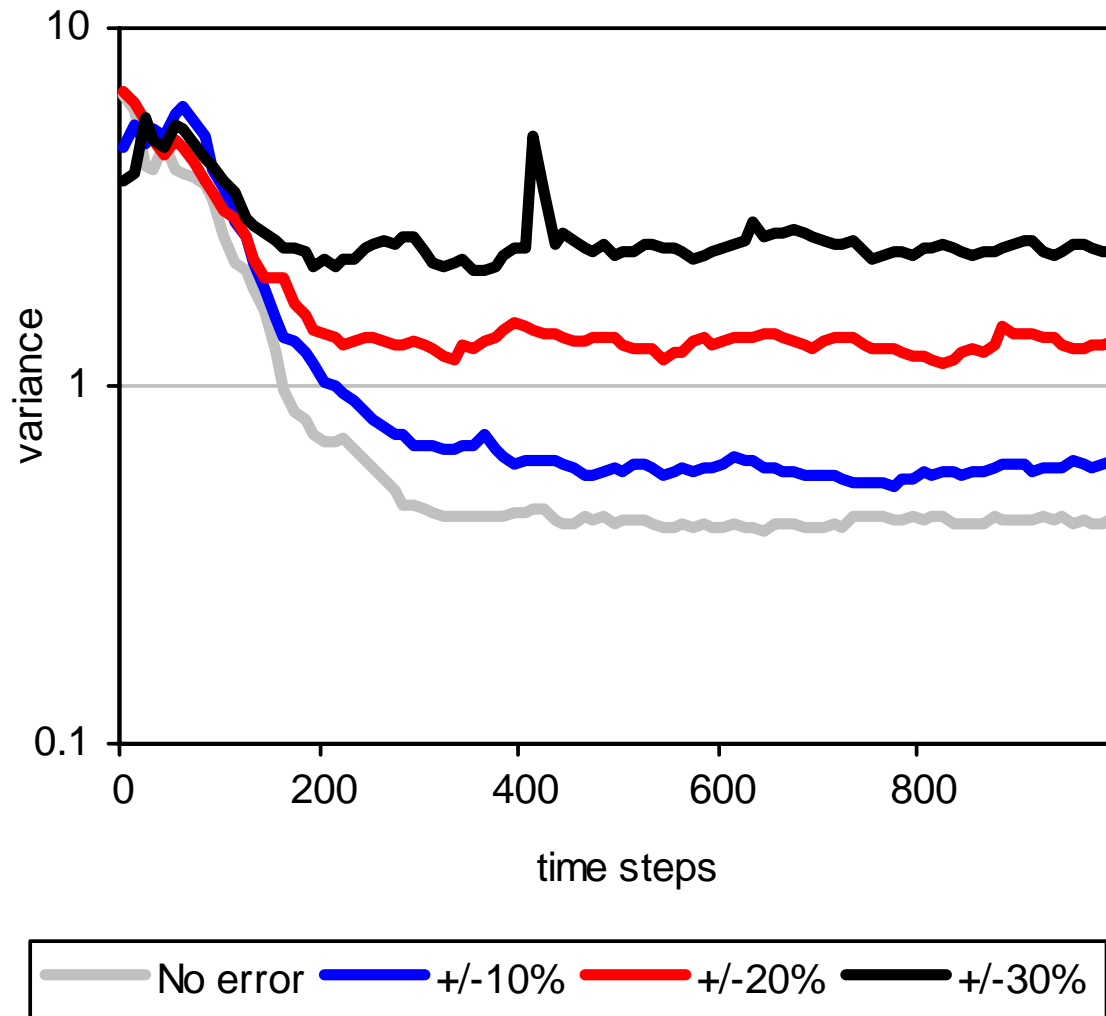
Simulation



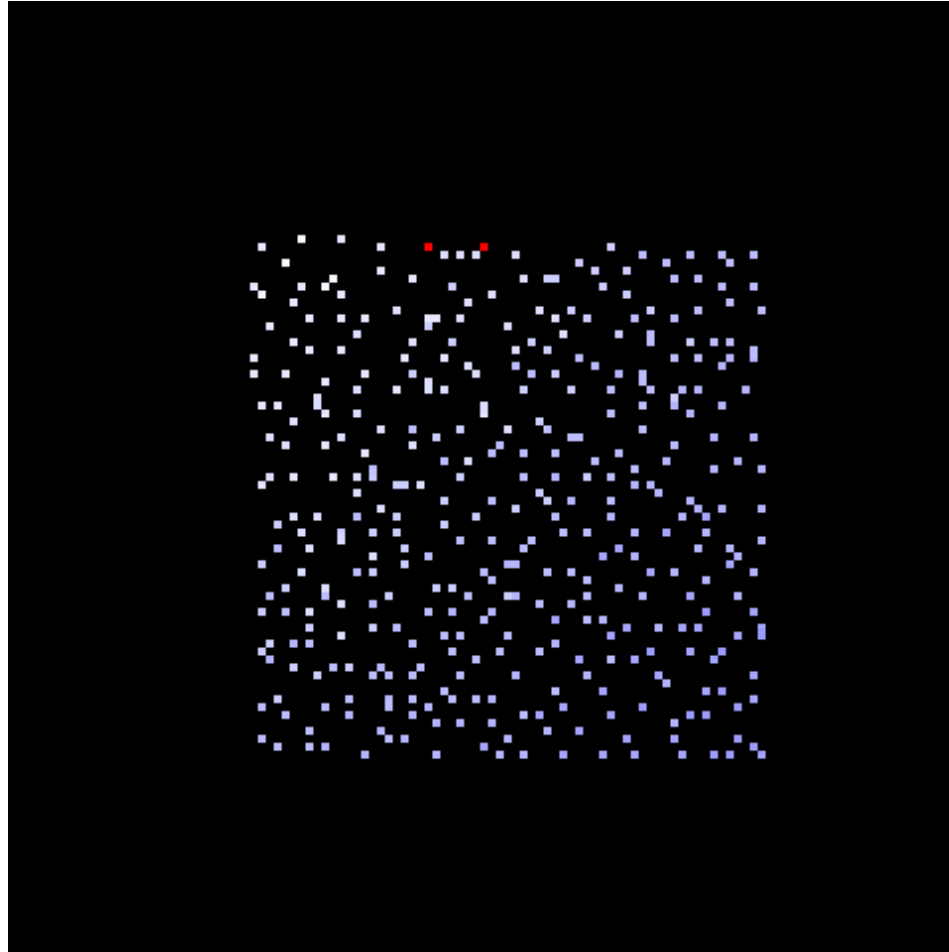
Proximity sensor error



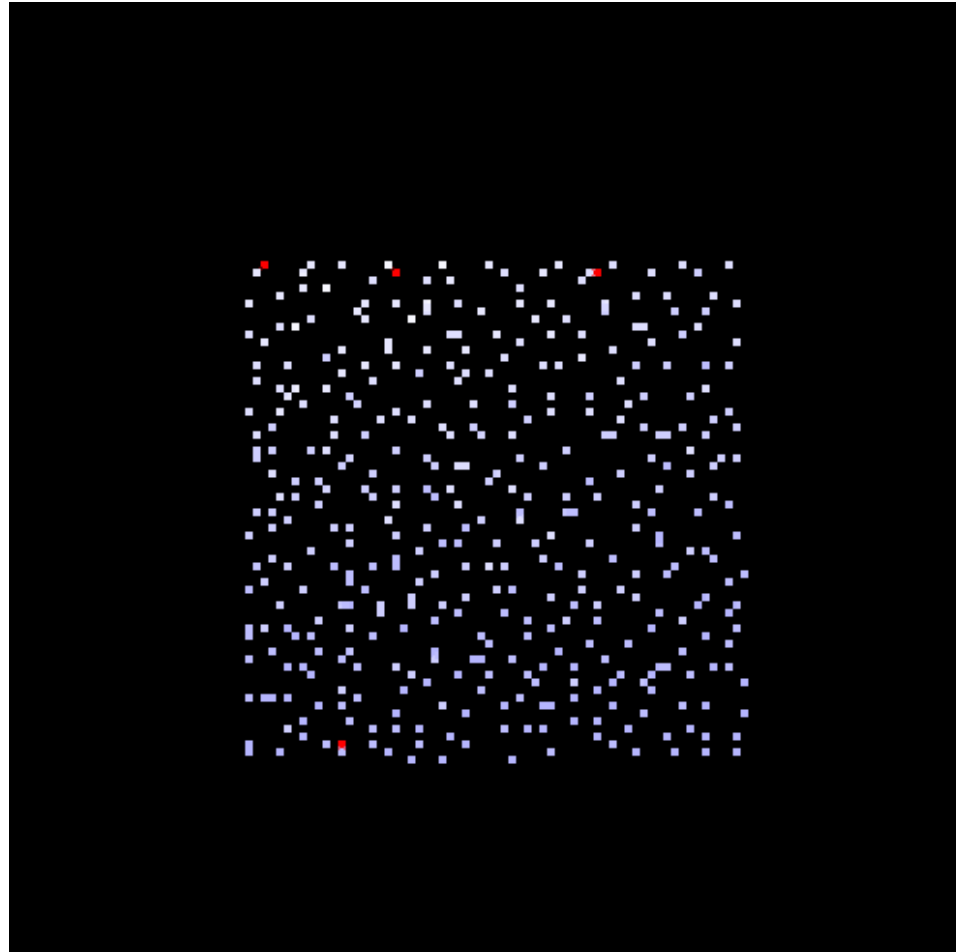
Movement error



Results: Self-repair



Results: Displaced agents



Previous work

- Leader-based approaches [Fredslund and Mataric et al, 2002, Mamei et al., 2004]
- Decentralized shape formation [Gordon et al., 2003]
- Gas expansion and flocking [Payton et al., 2001, Reynolds, 1987]

Summary

Shapebugs composes two processes

- Repeated, averaged trilateration
- Contained Gas movement.

Shown to be robust against

- Movement and sensor errors
- Agent death and displacement

Ongoing and future work

- Active recruiting for agents
- Coordinated movement in formation

