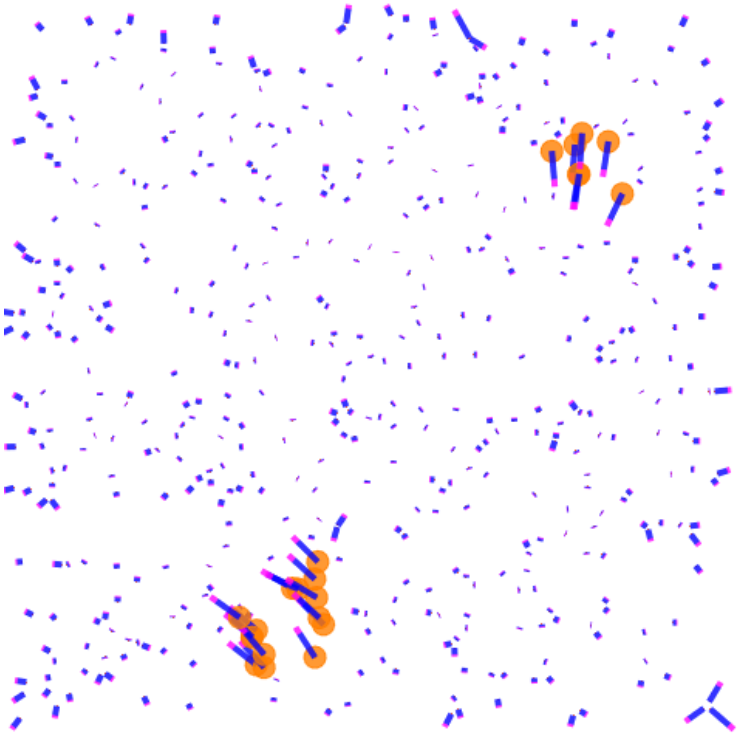
Moving Devices

Jacob Beal

Lecture 4 of 5 on Spatial Computing
ISC-PIF Summer School, 2009

BBN TECHNOLOGIES

or: search & rescue in ~50 lines...



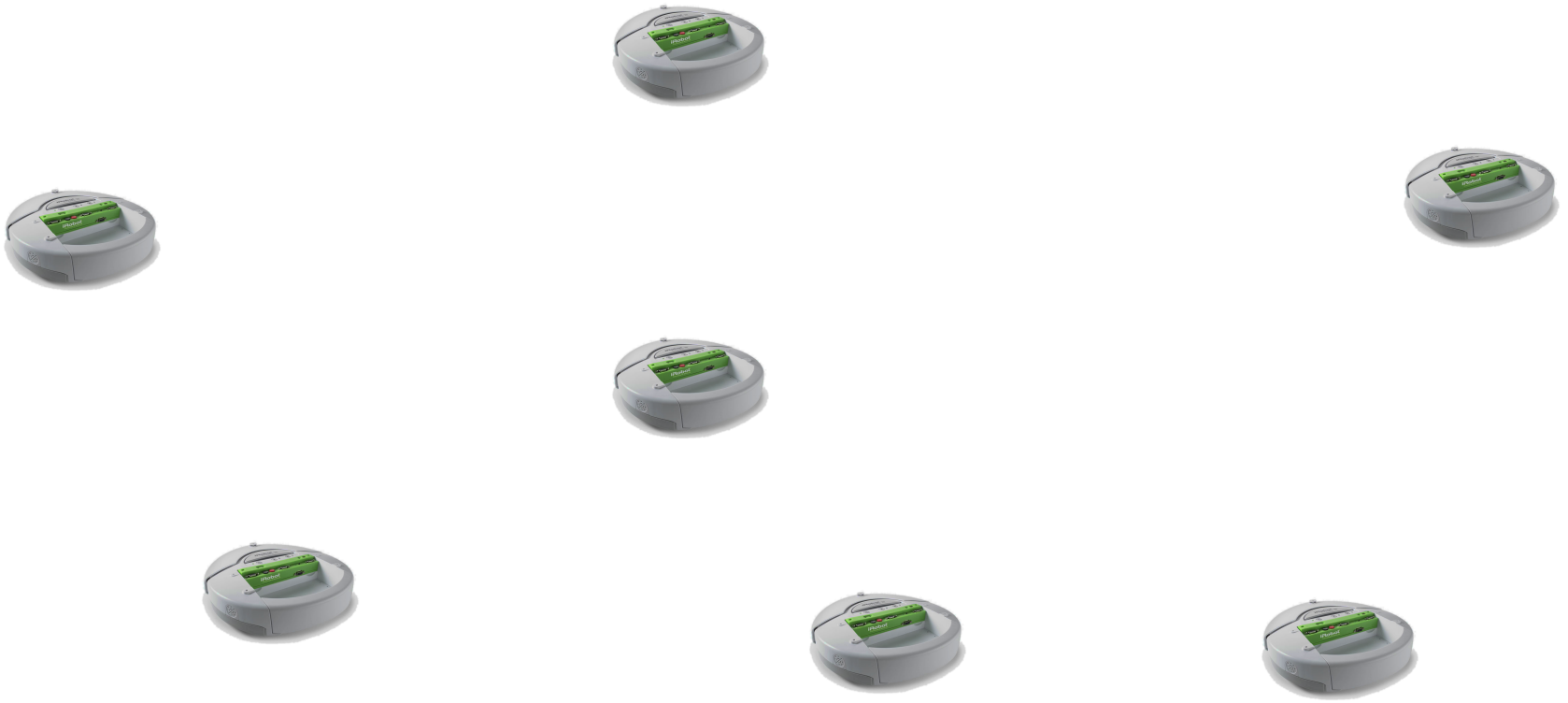
Robot motion = vector fields

Agenda

- Amorphous Medium for Mobile Devices
- Motion from Vector Fields
- Deployment Pragmatics

From one robot, to many

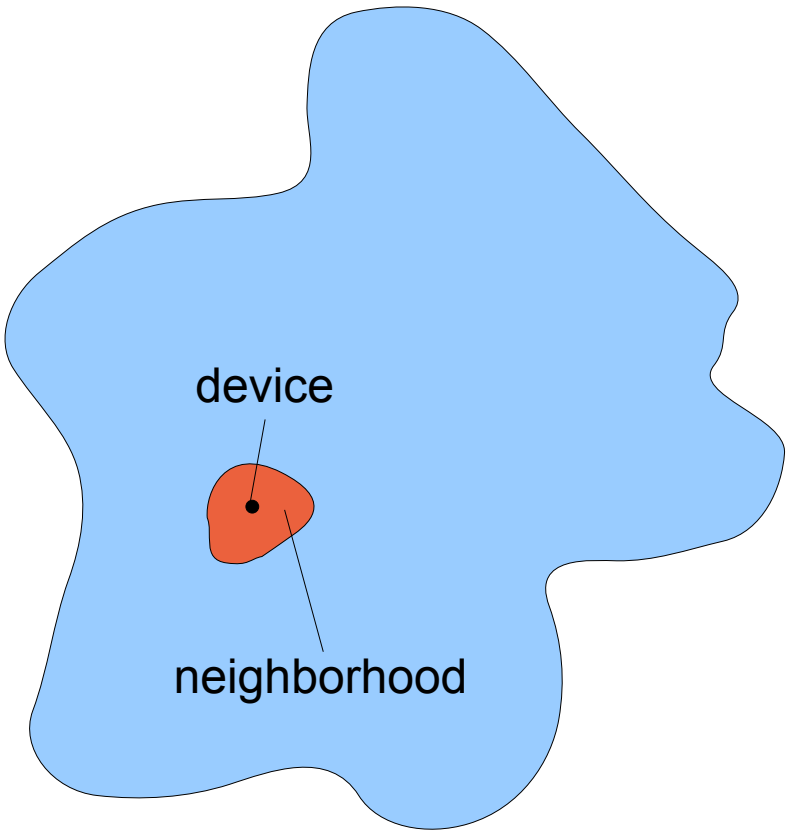
From one robot, to many

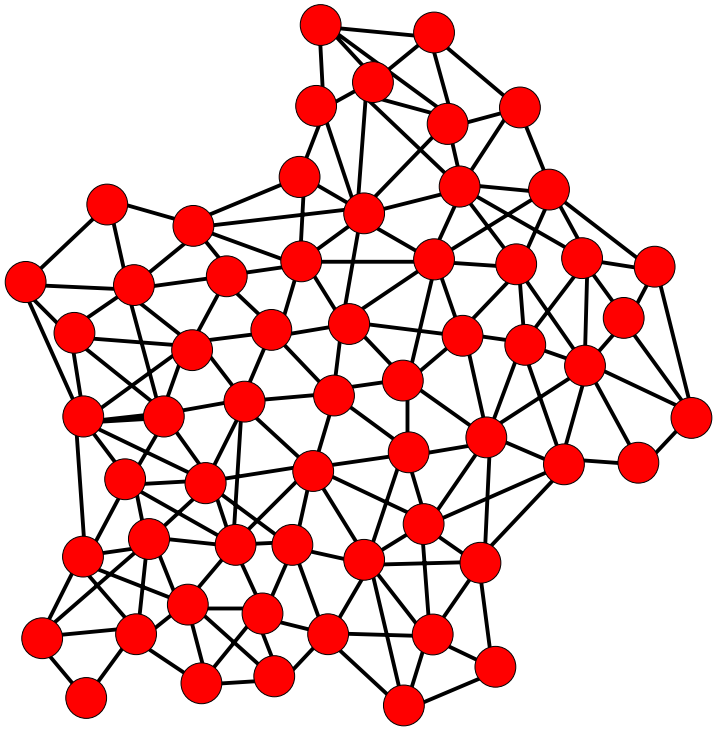


From one robot, to many

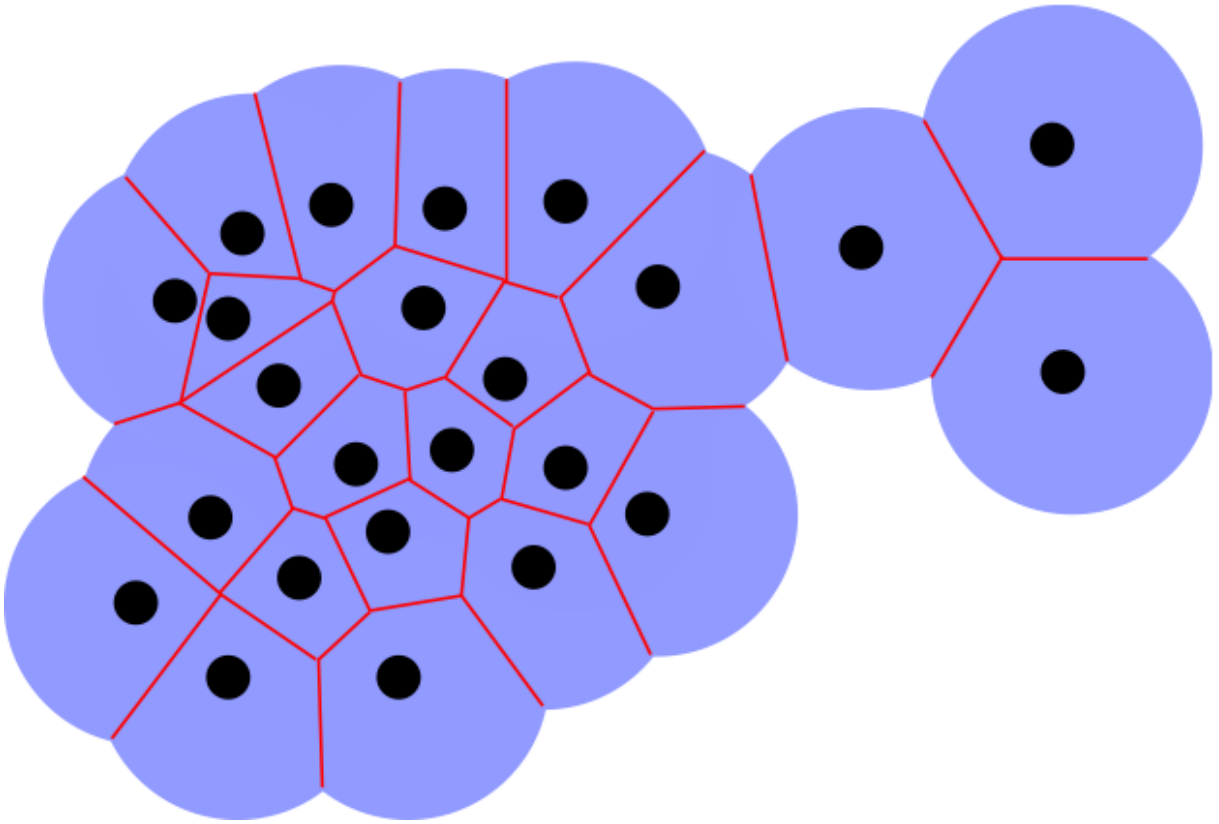
Robotic density is currently very low, but...

Space/Network Duality

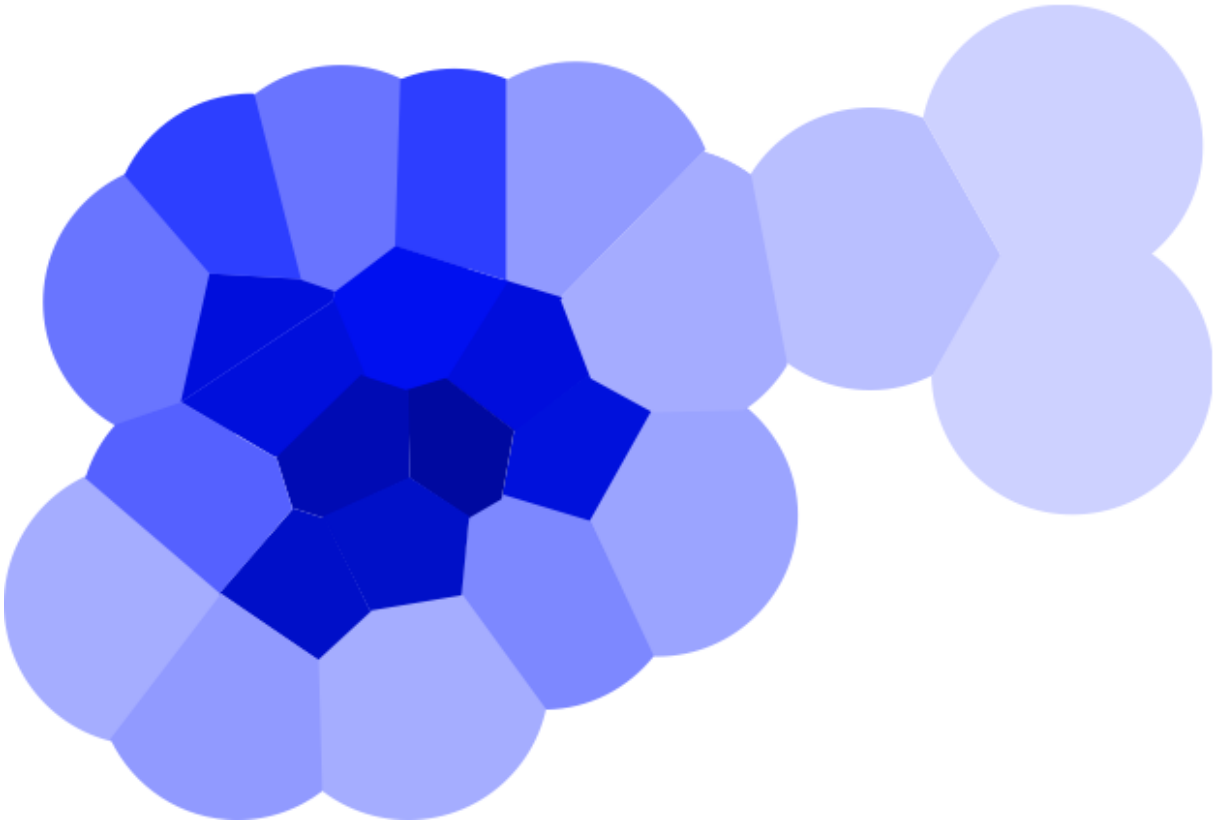




Mass & Density



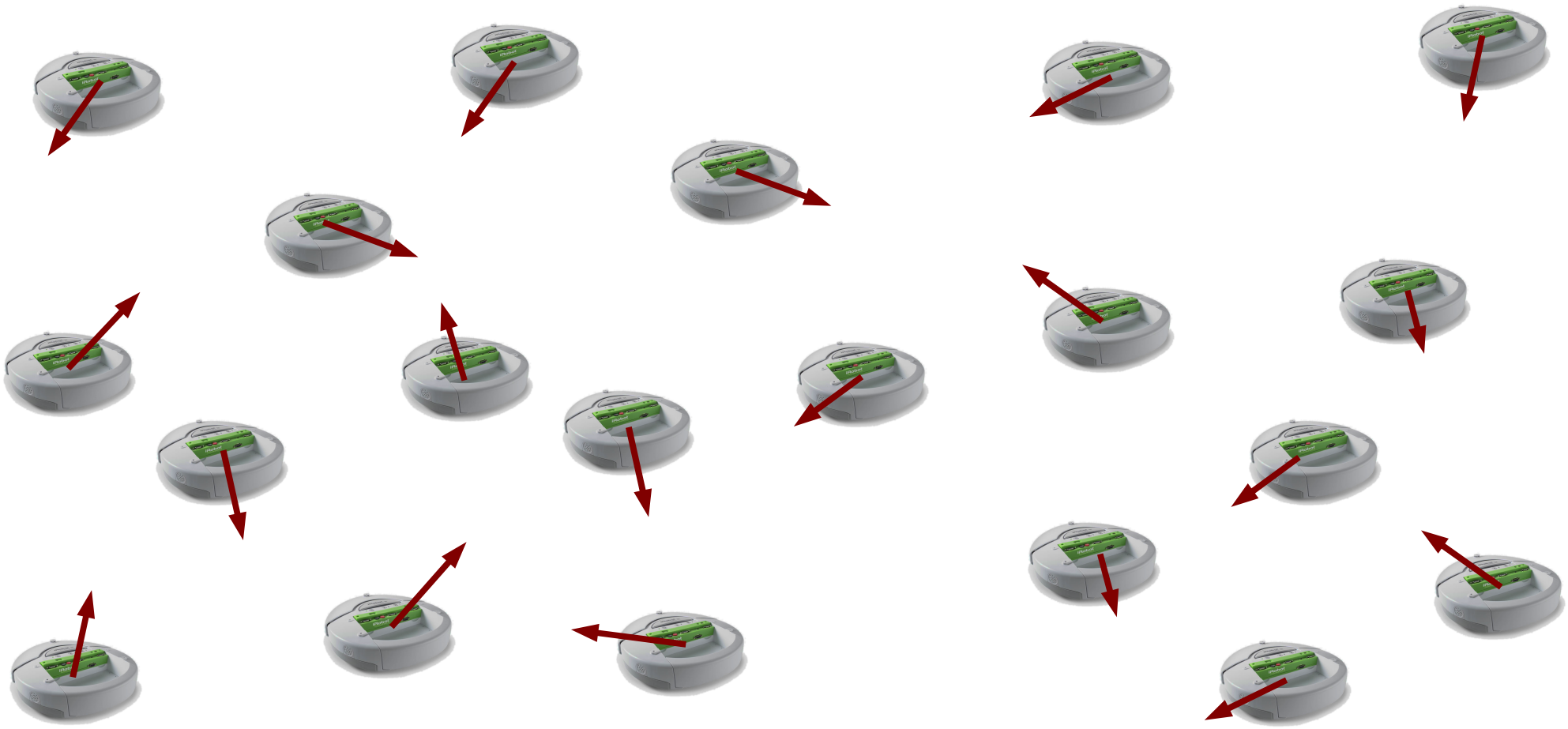
Mass & Density



$$\rho = \frac{1/4\,\pi\, r^2}{V}$$

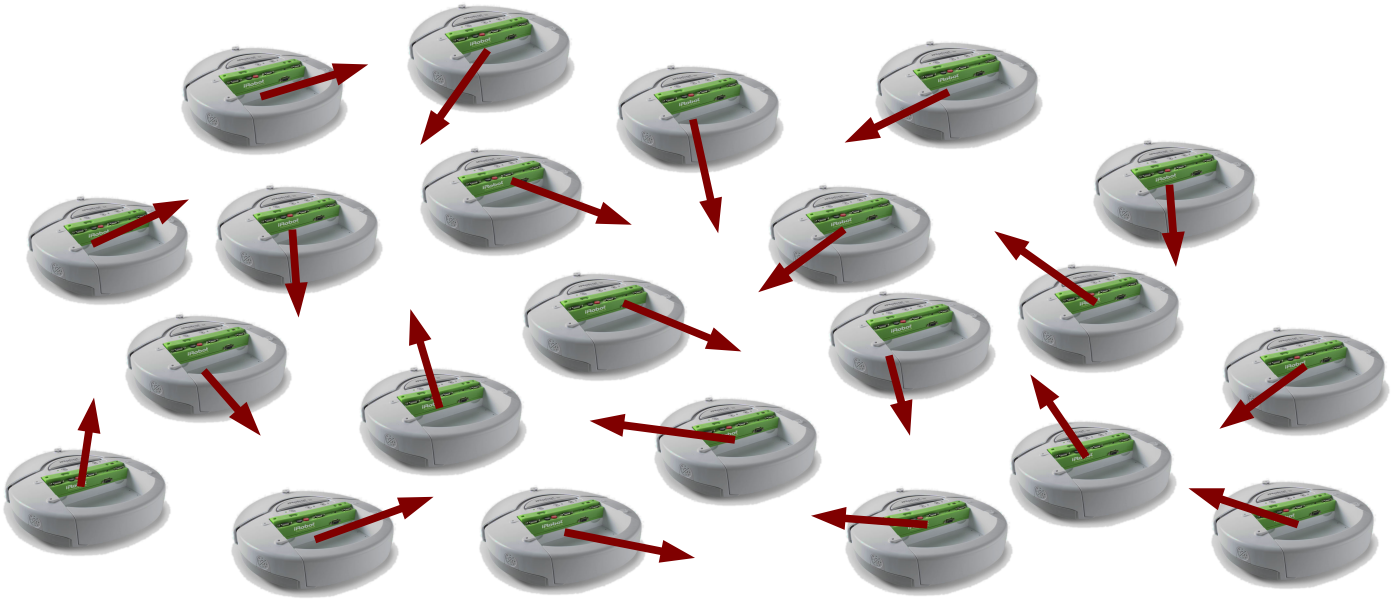
Device motion = mass flow

States of Robotic Matter



Gas: motion is largely unconstrained

States of Robotic Matter



Liquid: motion is locally constrained

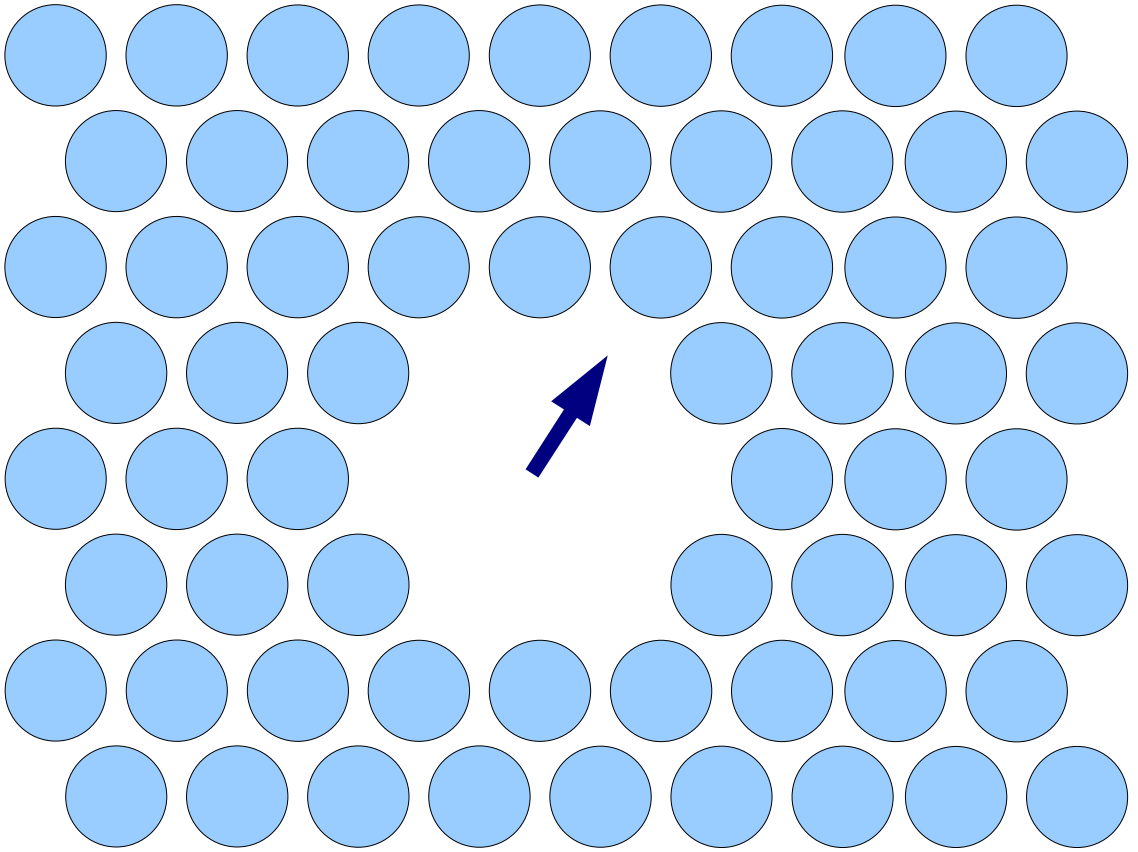
Robots move *around* one another

States of Robotic Matter

Solid: packed so tightly that only a few can move

How might robots move in solids?

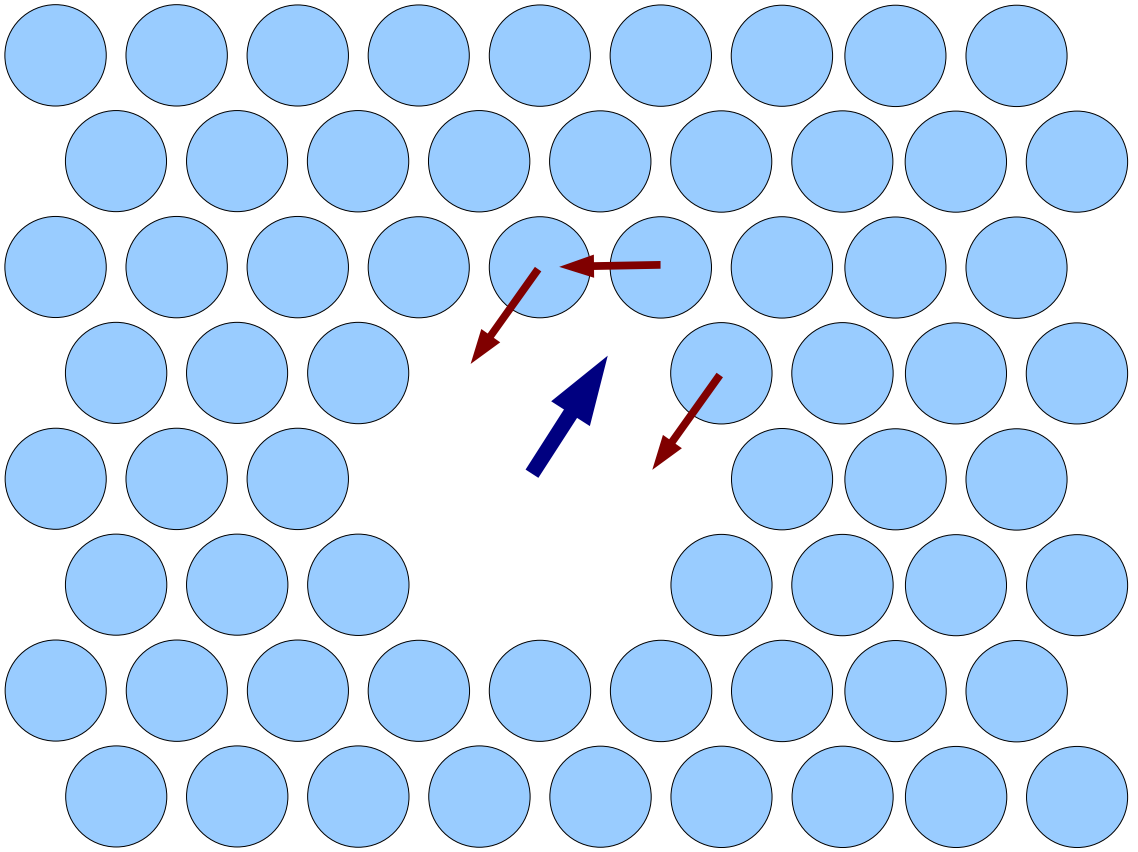
Hole Motion



Robots move like positive semiconductor charge

[De Rosa et al, '06]

Hole Motion



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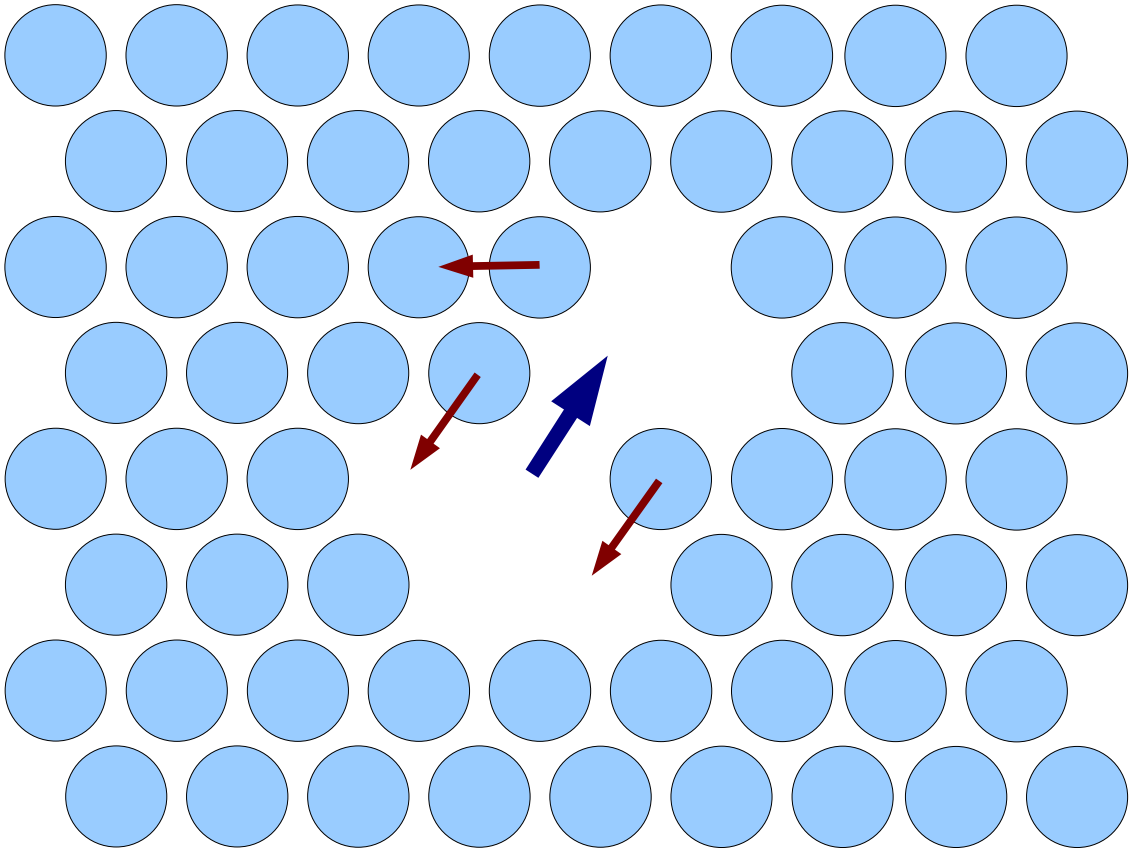

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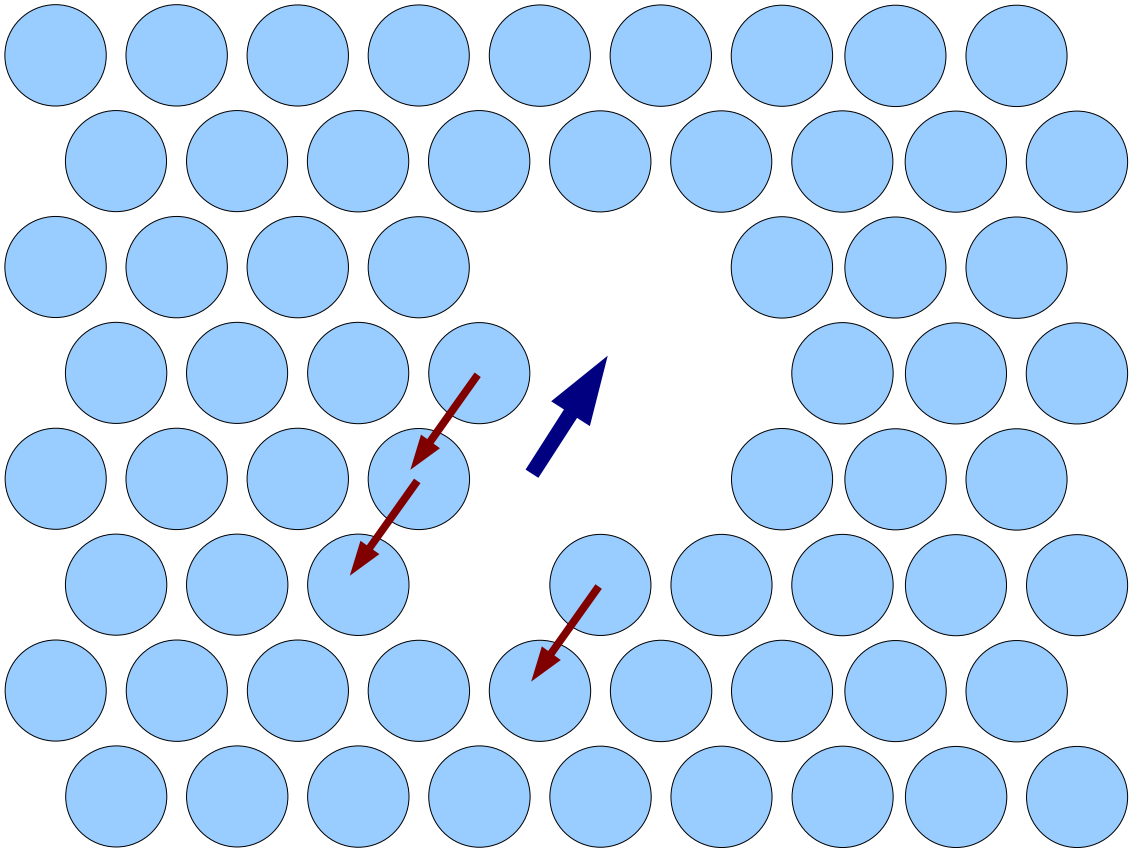

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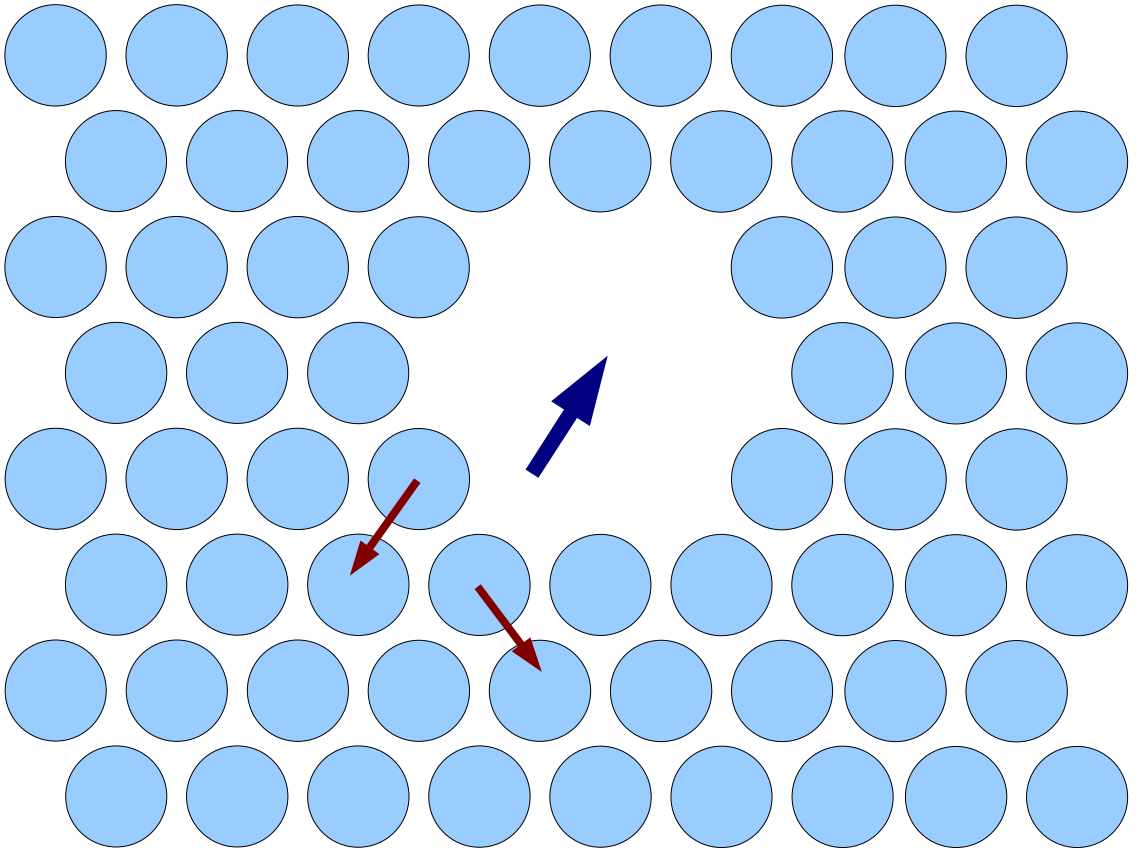

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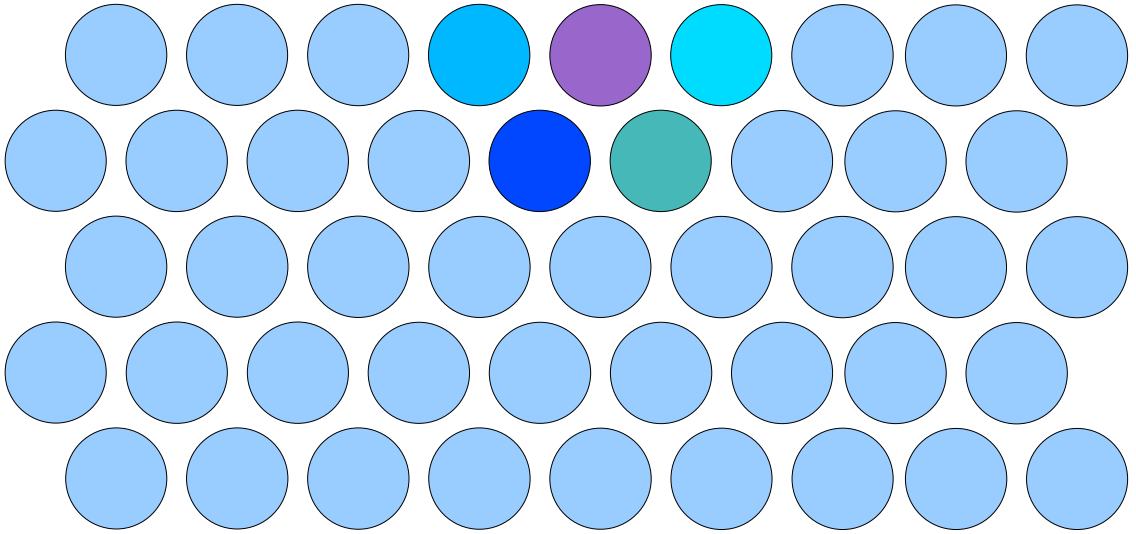
[De Rosa et al, '06]

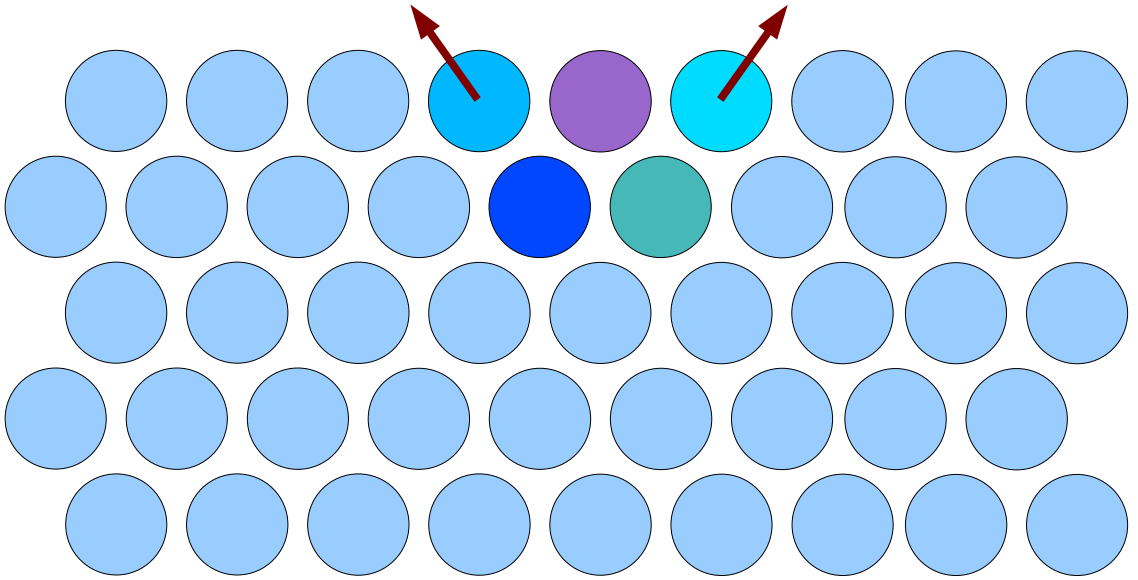
Forming a Hole



Surface blisters outward

[De Rosa et al, '06]

Forming a Hole



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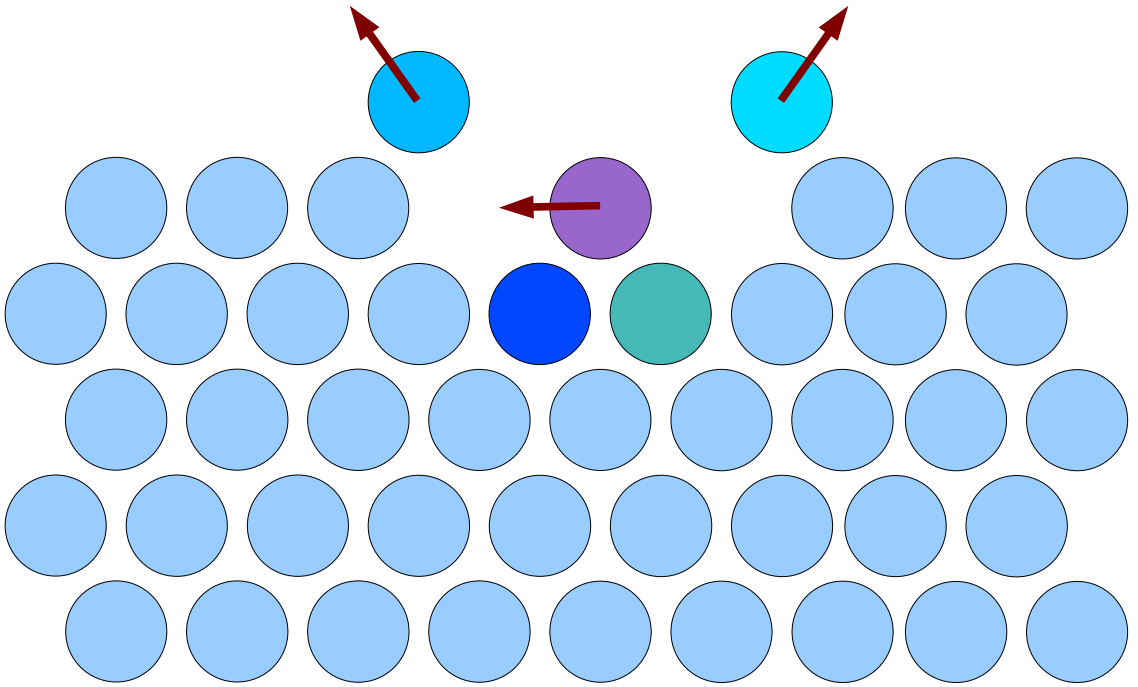

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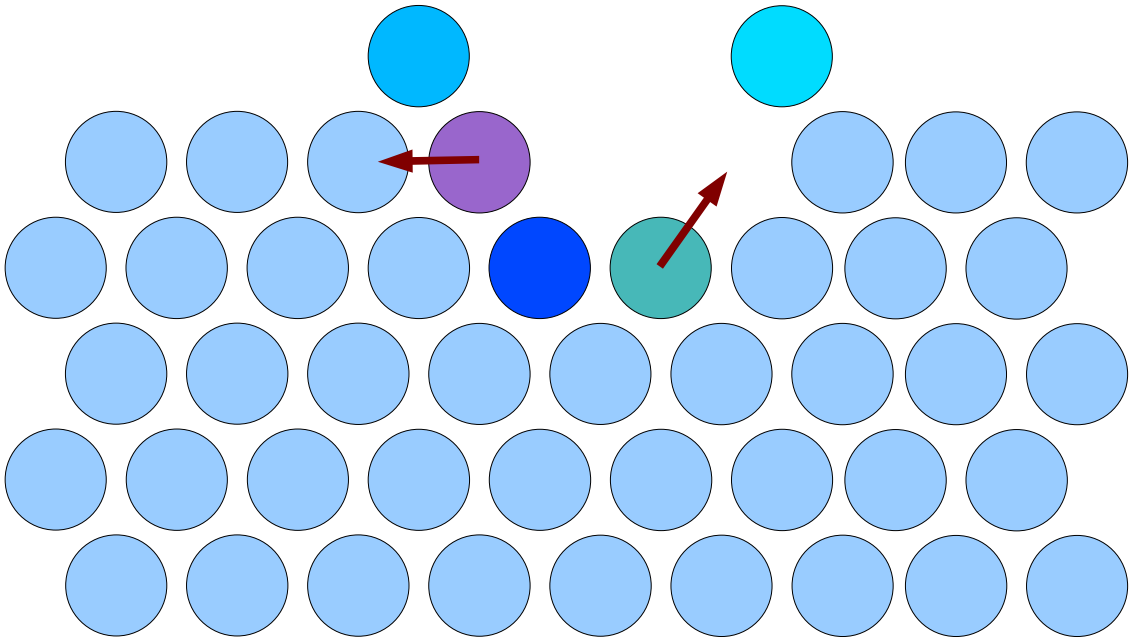

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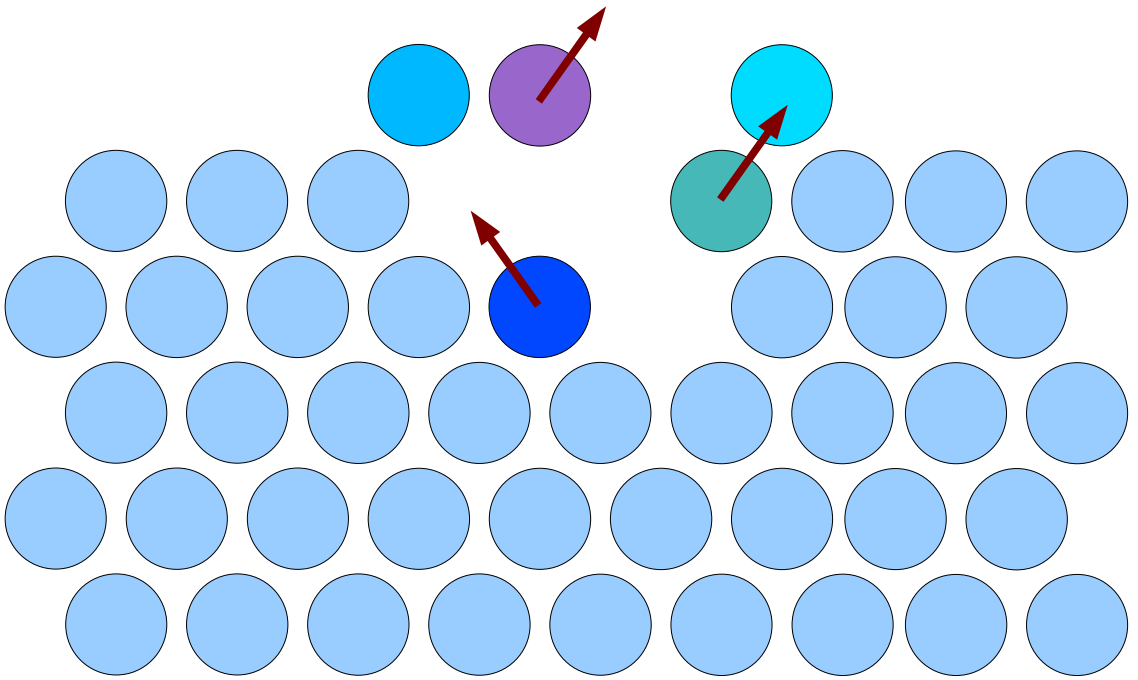

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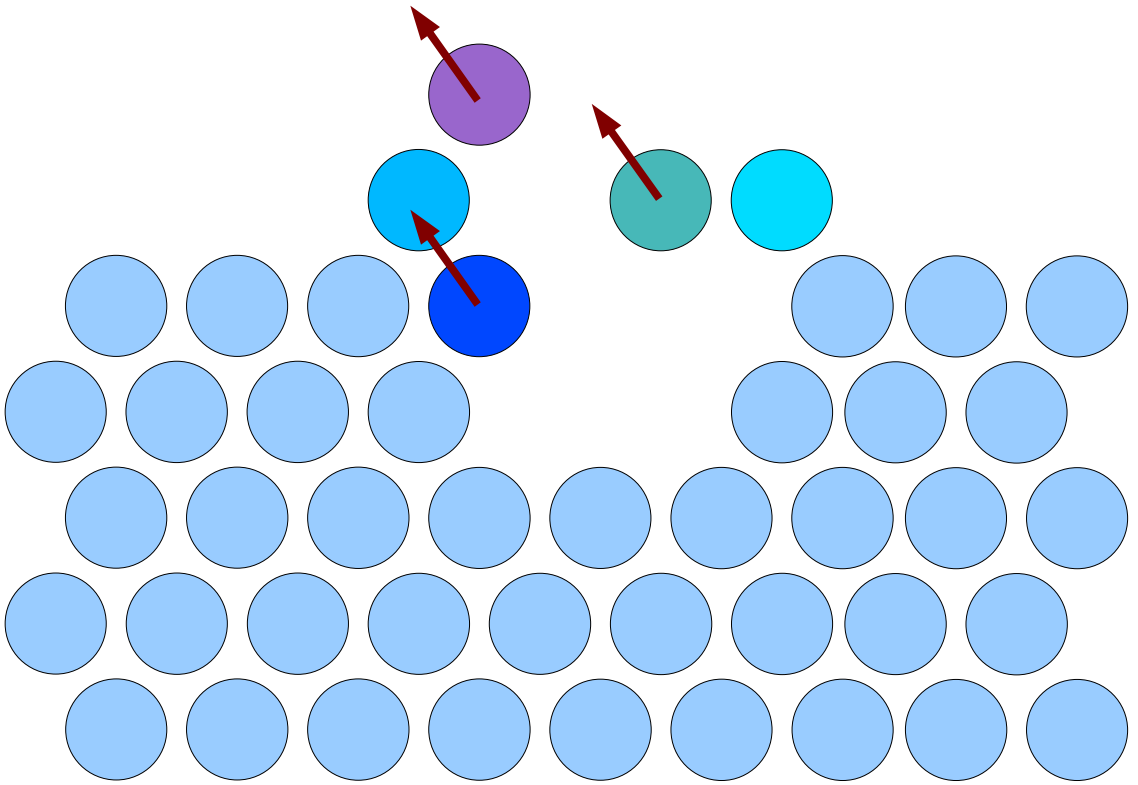

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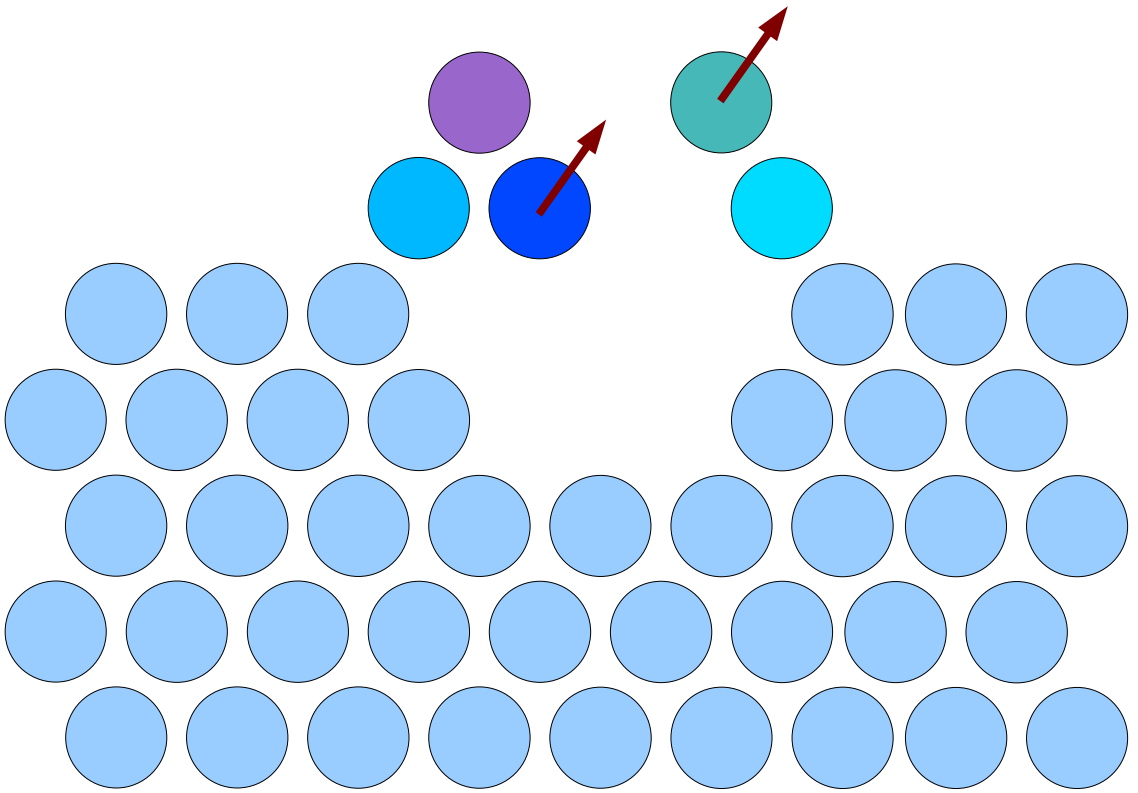

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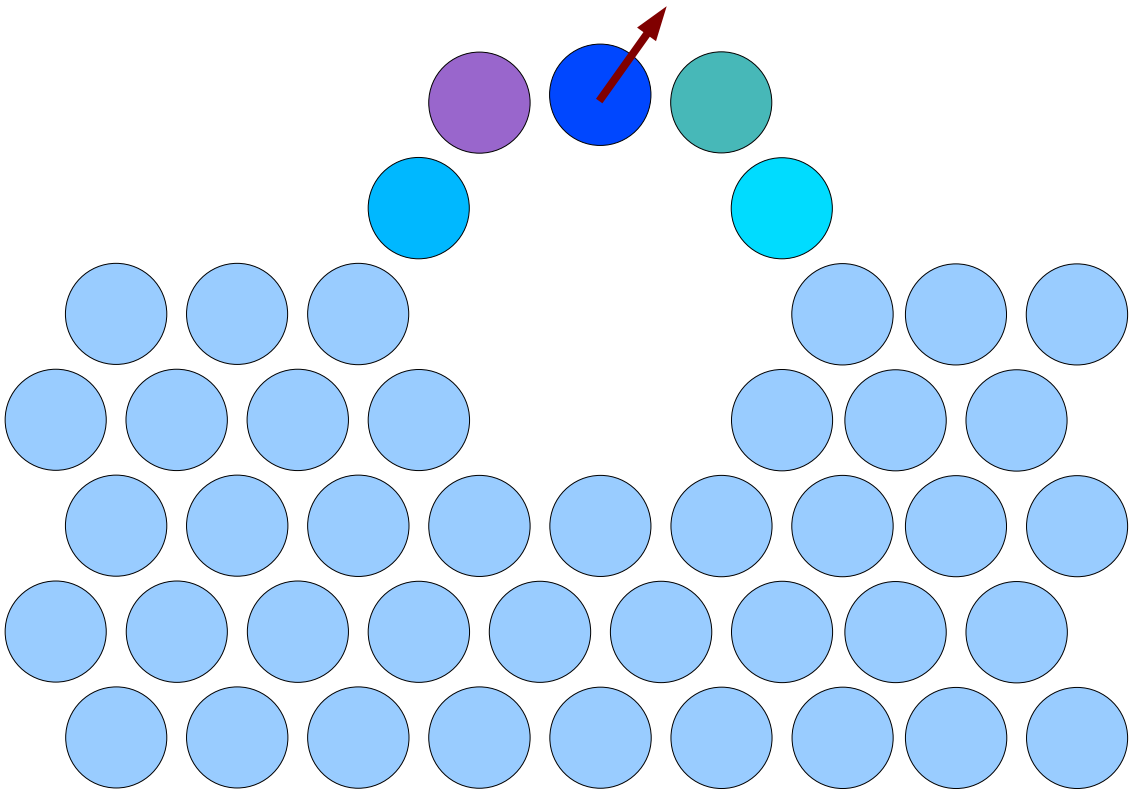

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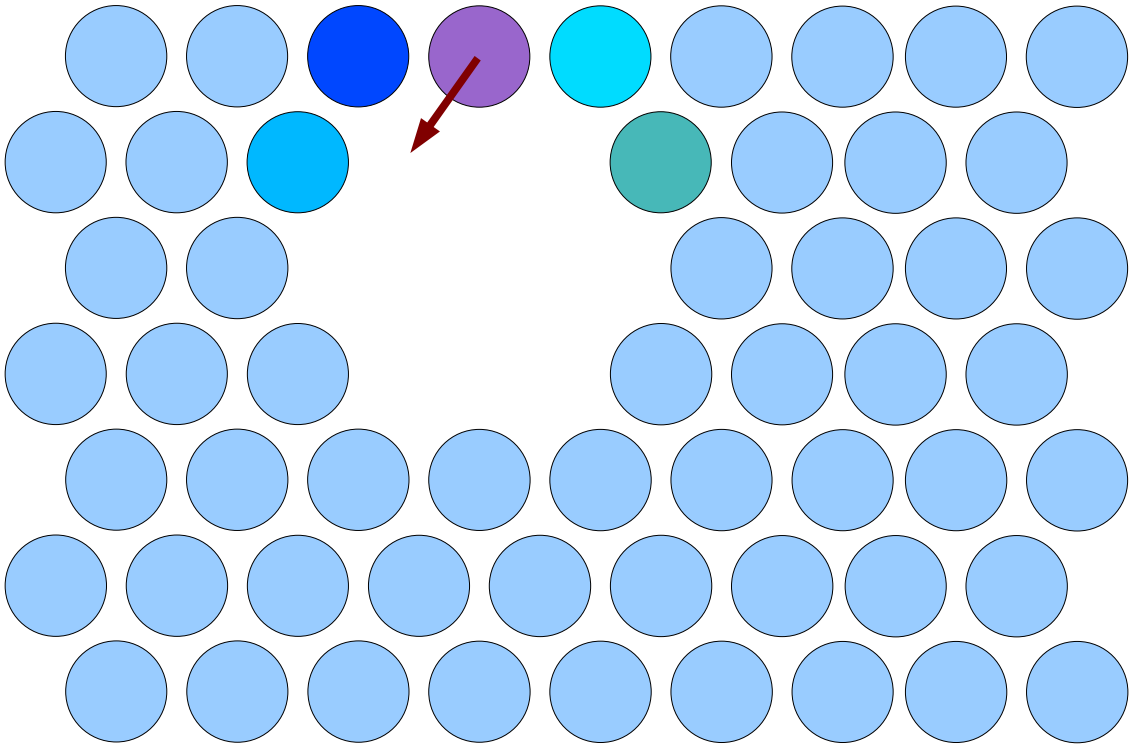
[De Rosa et al, '06]

Popping a hole



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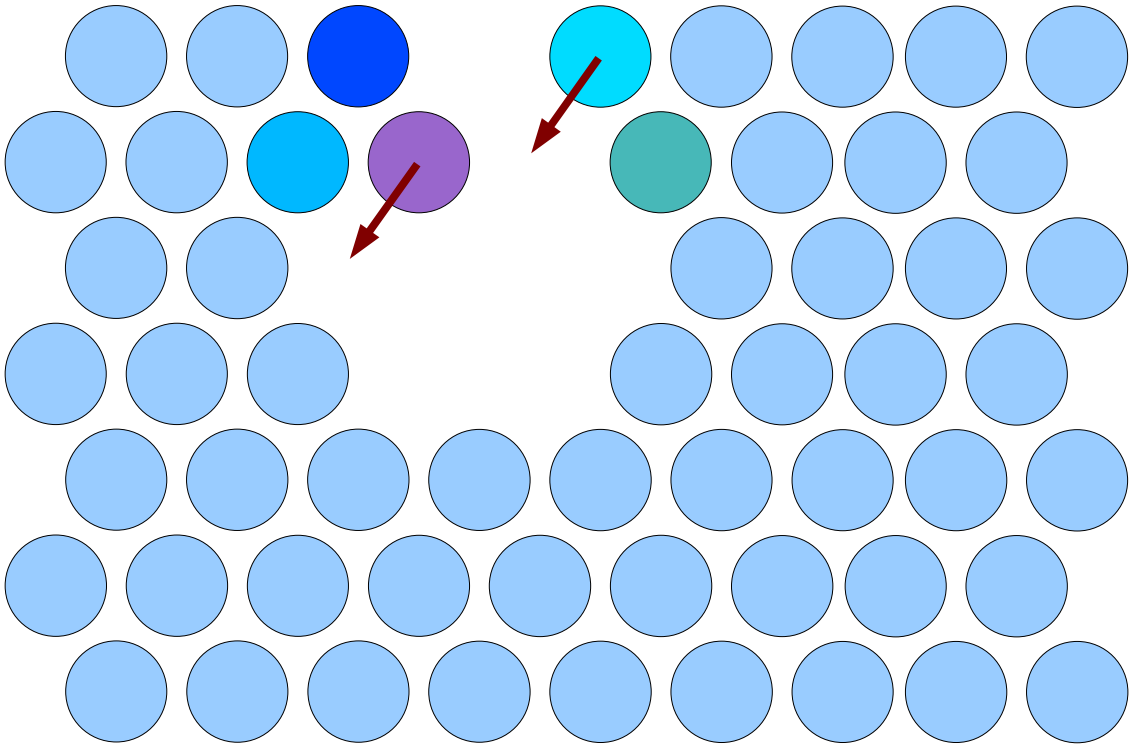

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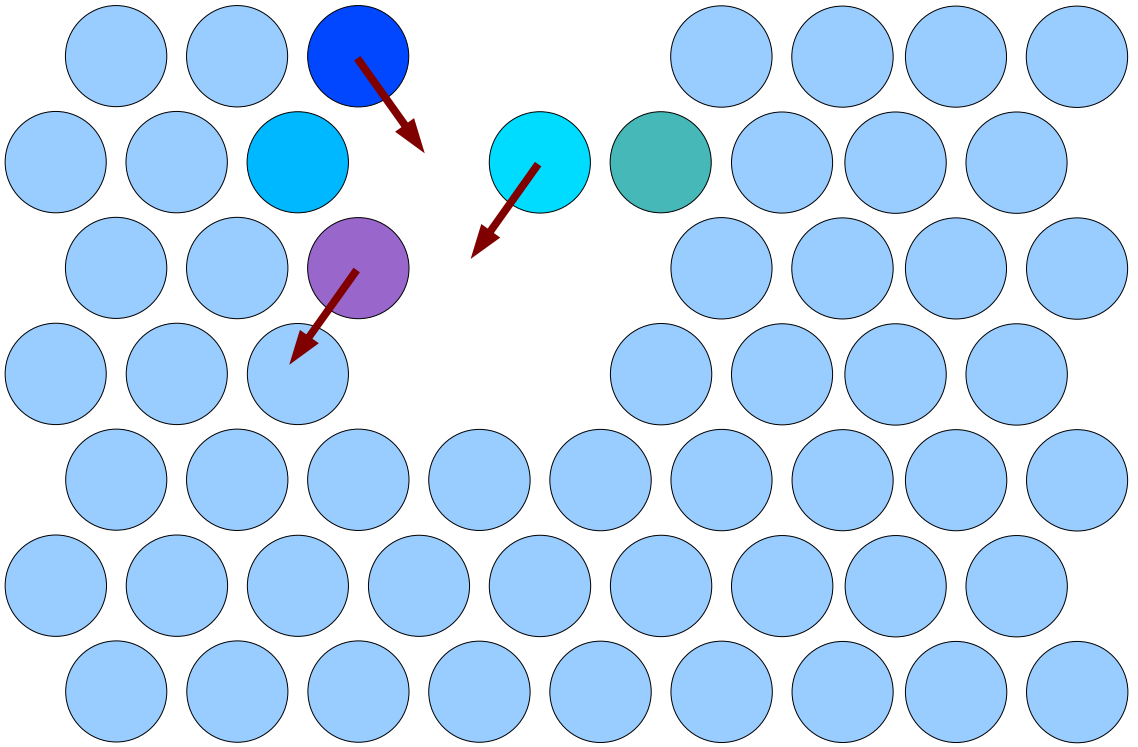

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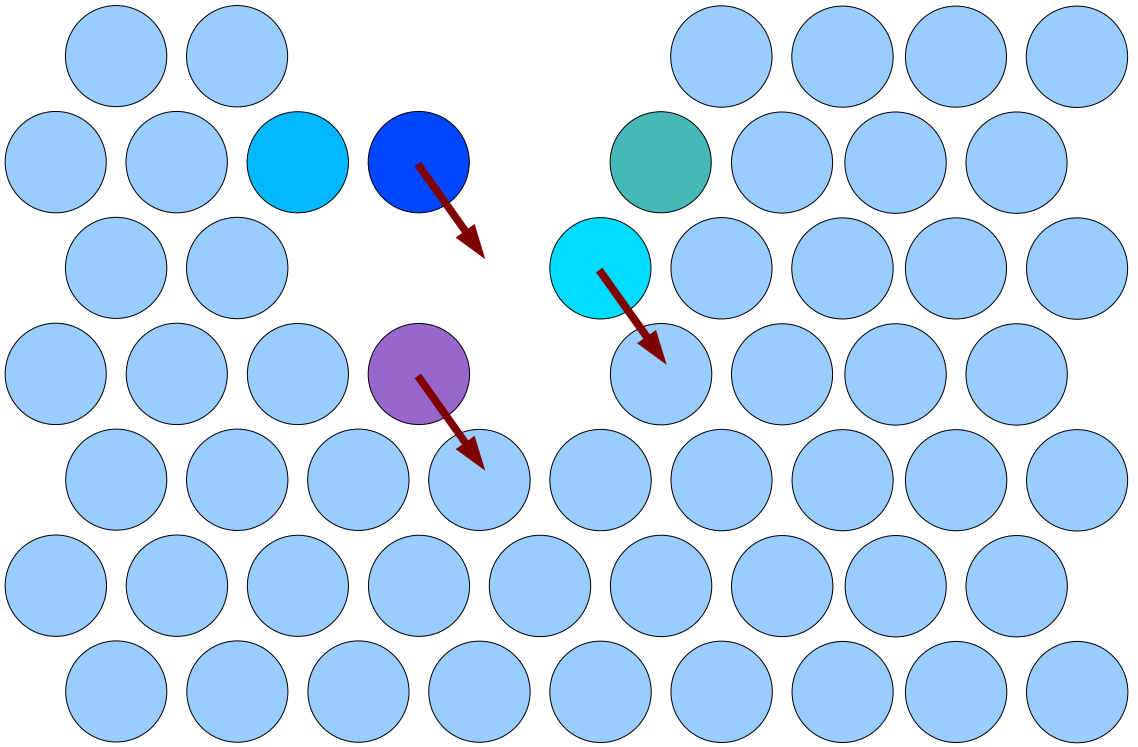

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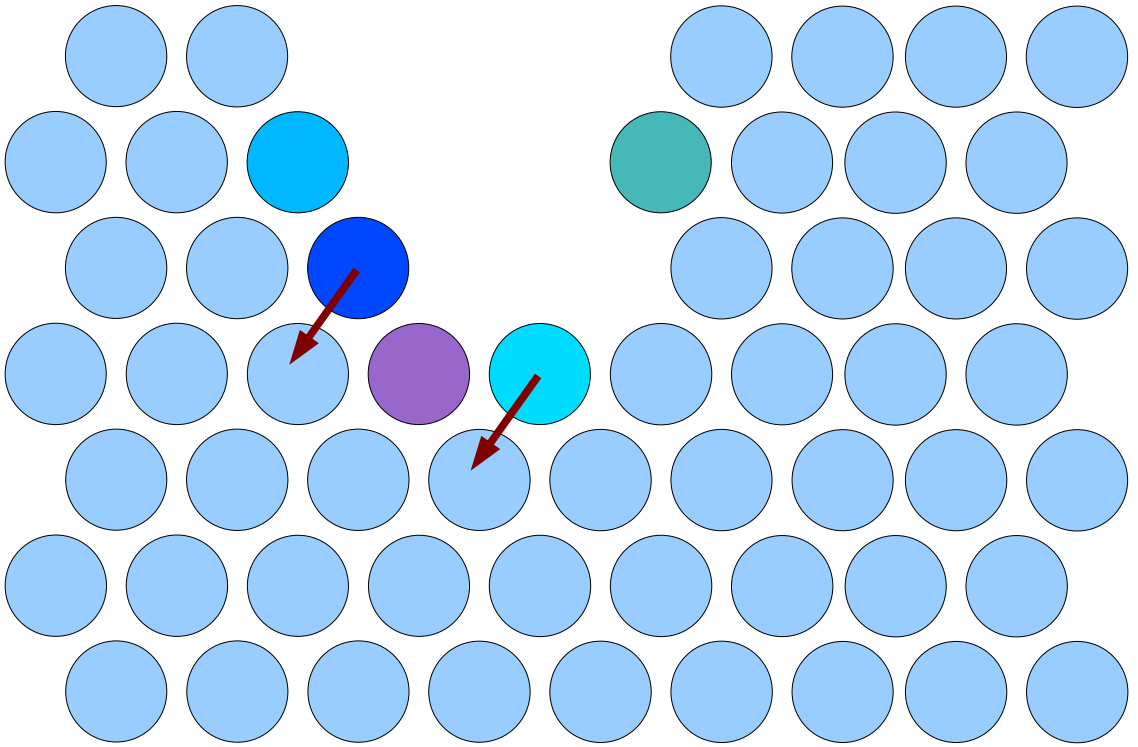

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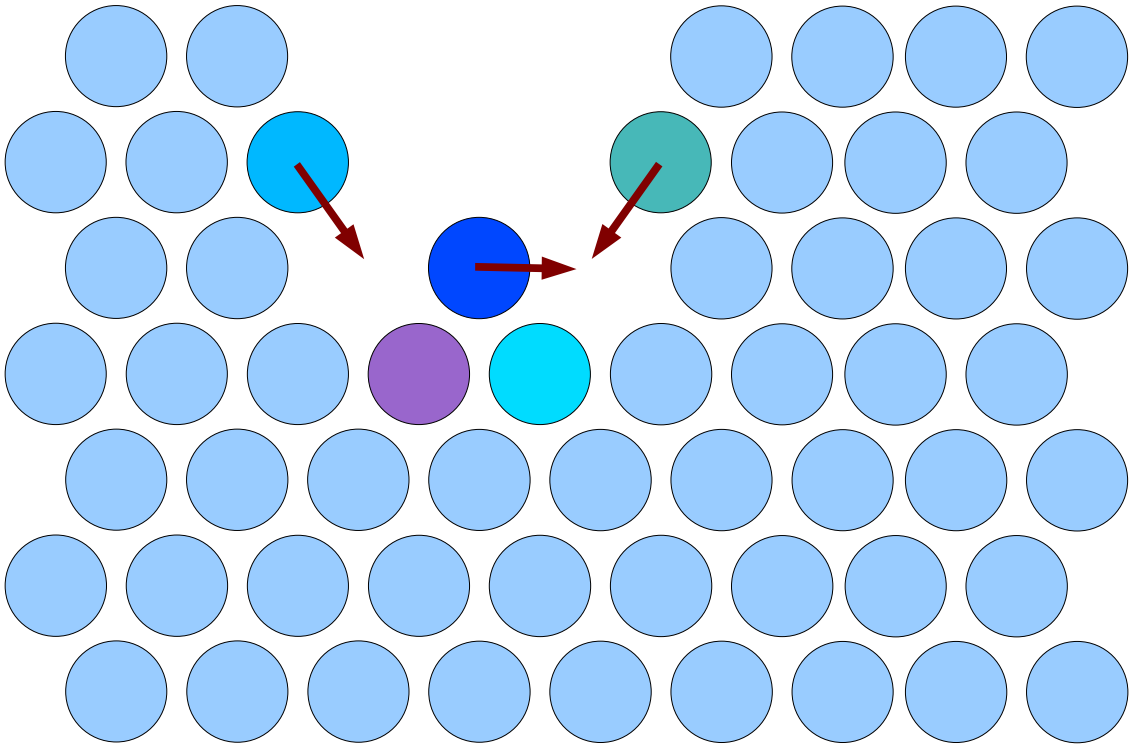

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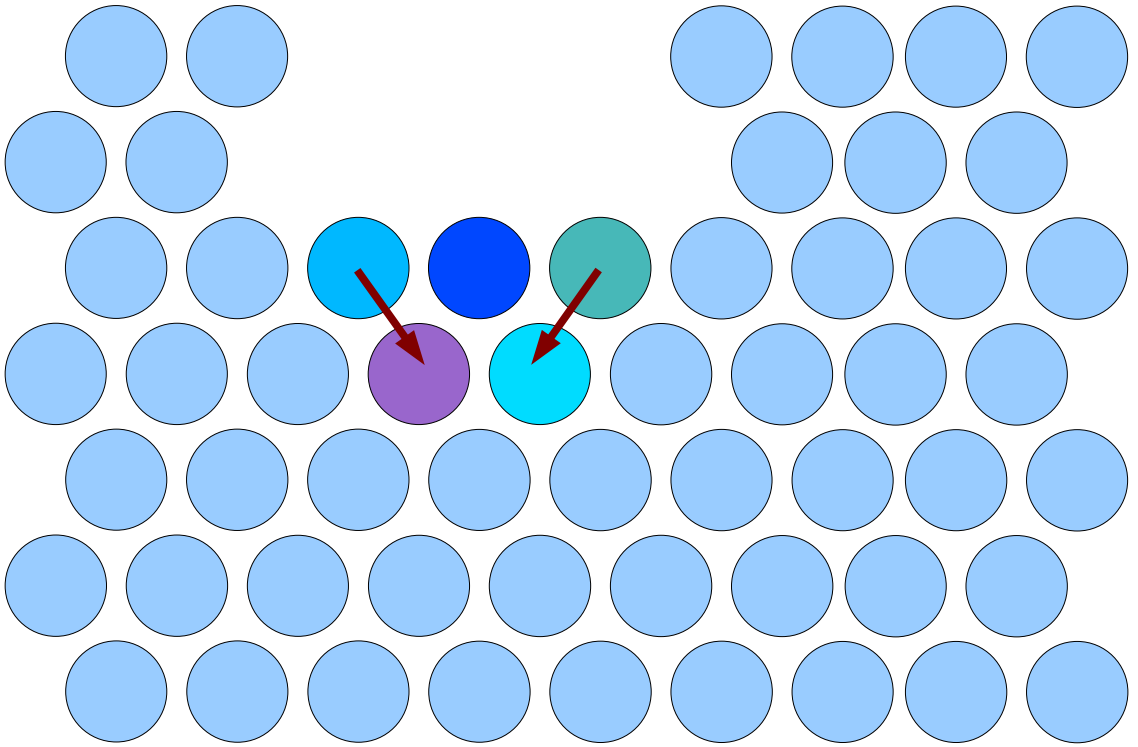
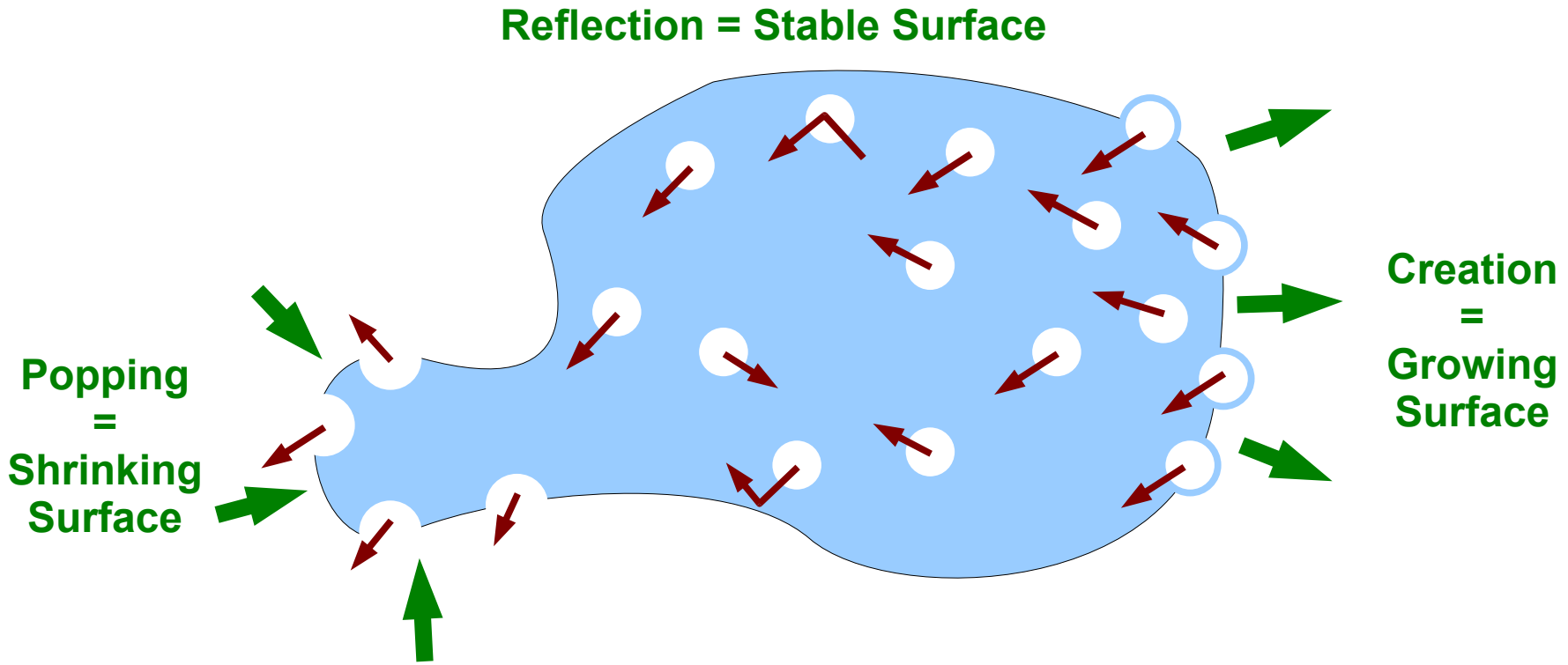


Surface blisters inward

[De Rosa et al, '06]

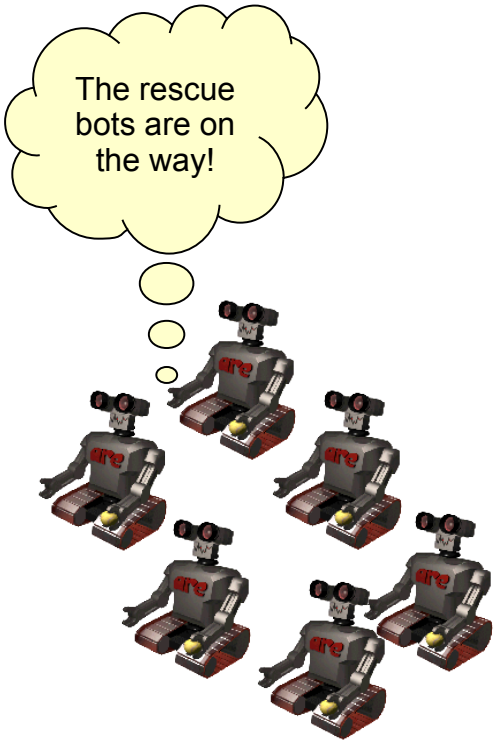
Surface/hole interaction → shape



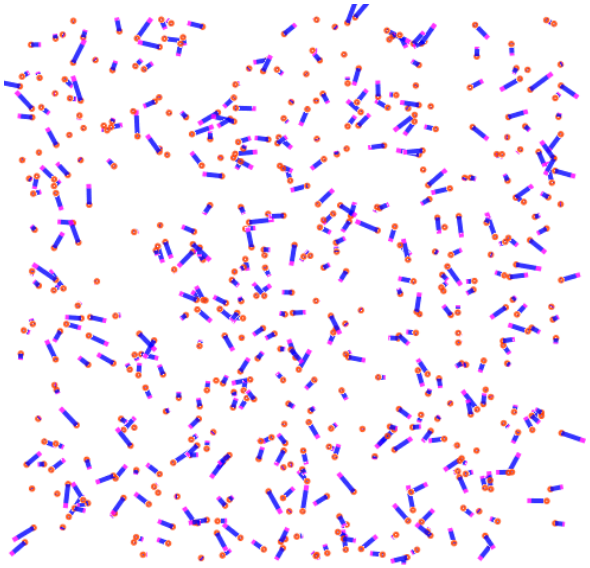
Agenda

- Amorphous Medium for Mobile Devices
- **Motion from Vector Fields**
- Deployment Pragmatics

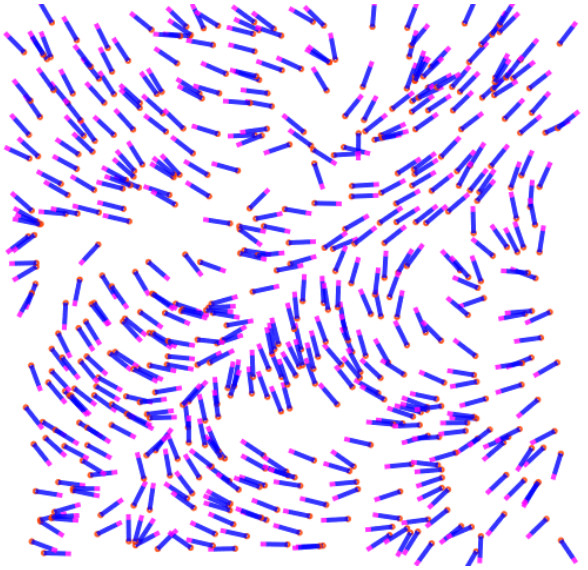
Example: Search & Rescue



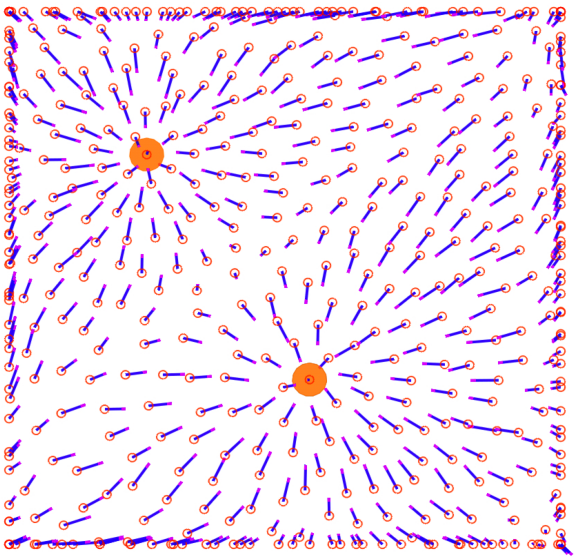
Robot Motion = Vector Fields



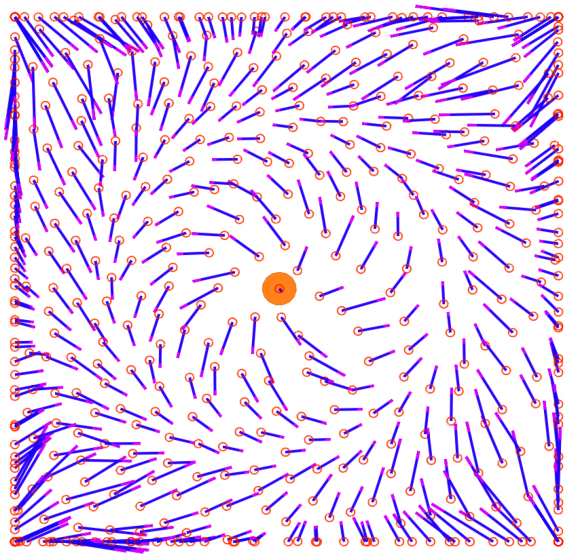
brownian



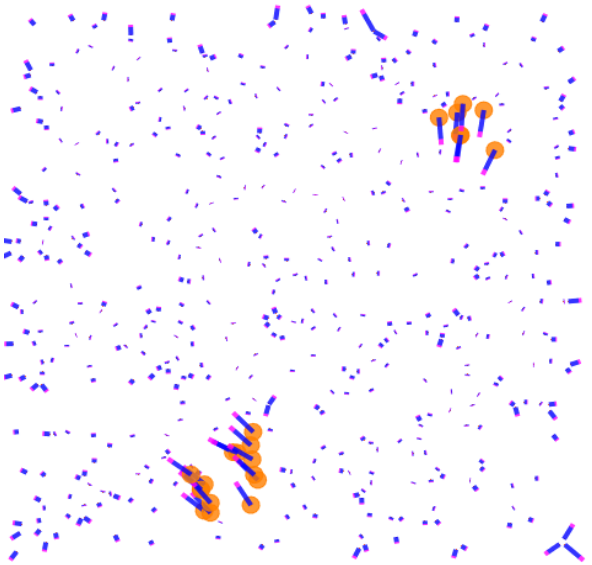
flock



cluster-to



contour-field

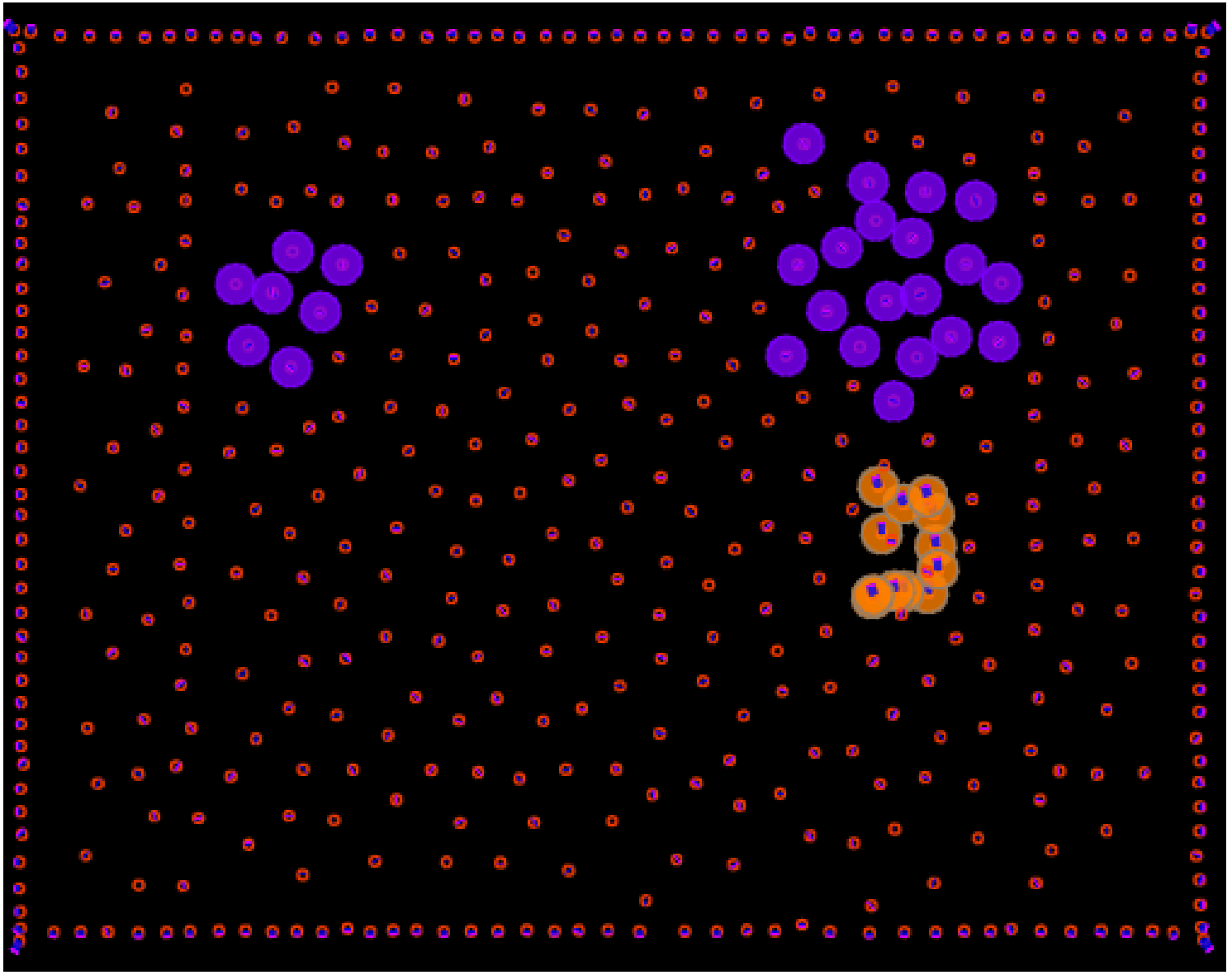


search-and-rescue

Programming Swarm Motion

Let's go work with some vector fields...

In simulation...



Agenda

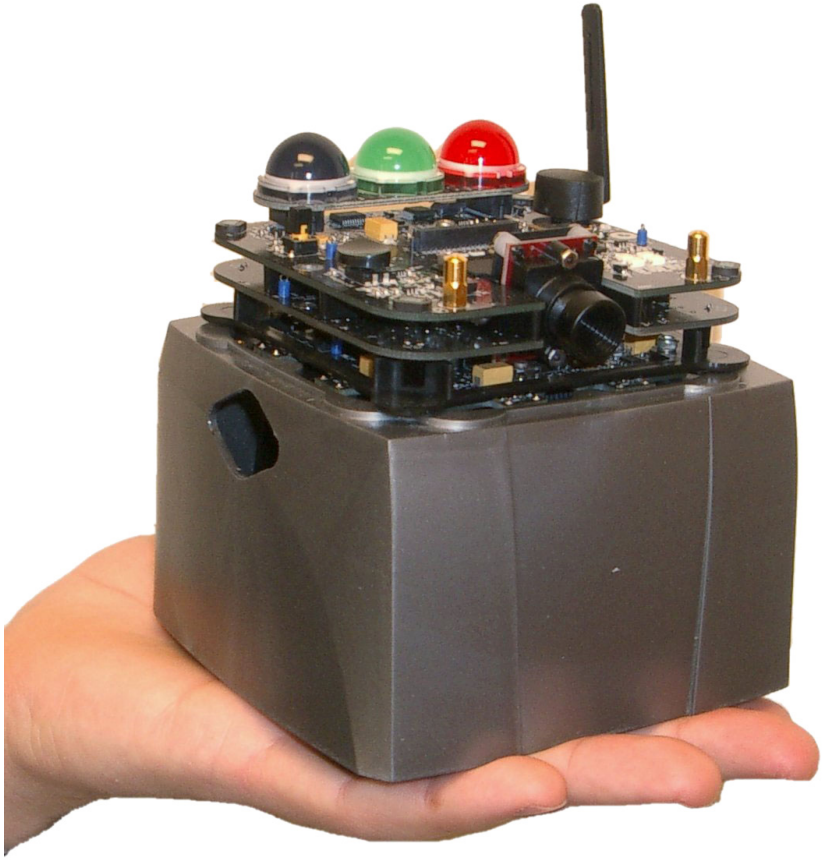
- Amorphous Medium for Mobile Devices
- Motion from Vector Fields
- **Deployment Pragmatics**

Deployment Challenges

Large numbers rule out human maintenance

- Programming or rebooting
  - Viral distribution, e.g. Deluge [Hui & Culler, 04], Trickle [Levis et al, '04]
- Energy
  - Power saving techniques
  - Harvesting, autonomous refuel/recharge
- Visbility of state (e.g. for debugging)

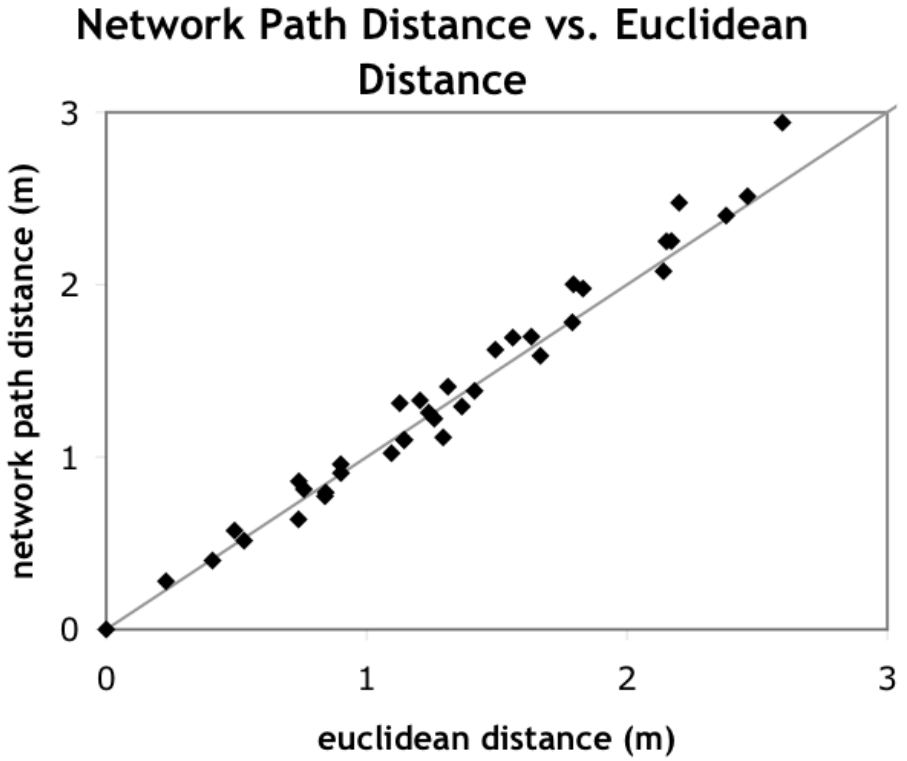
On McLurkin's SwarmBots



- Swarm of 40 robots

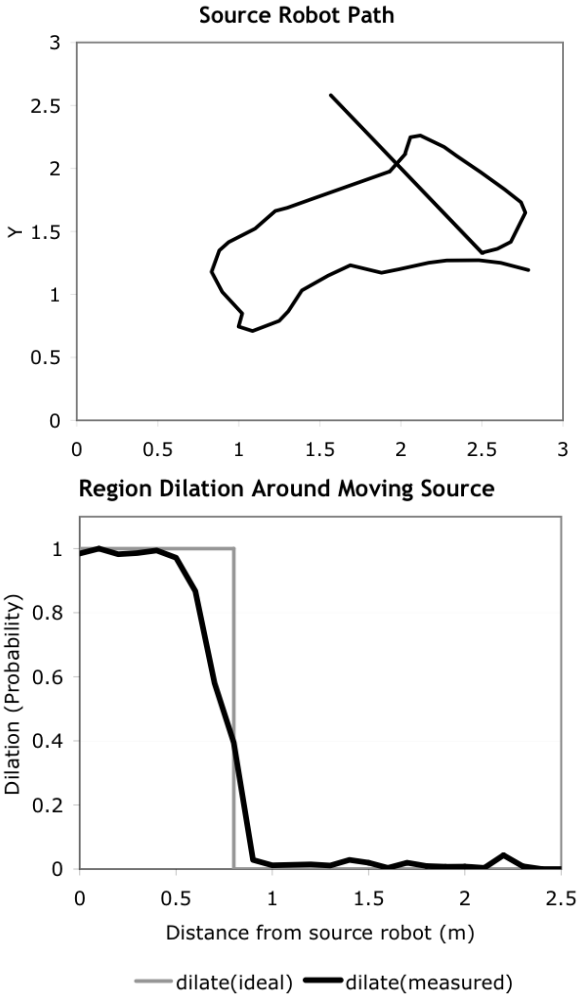
[Bachrach et al, '08]

On McLurkin's SwarmBots



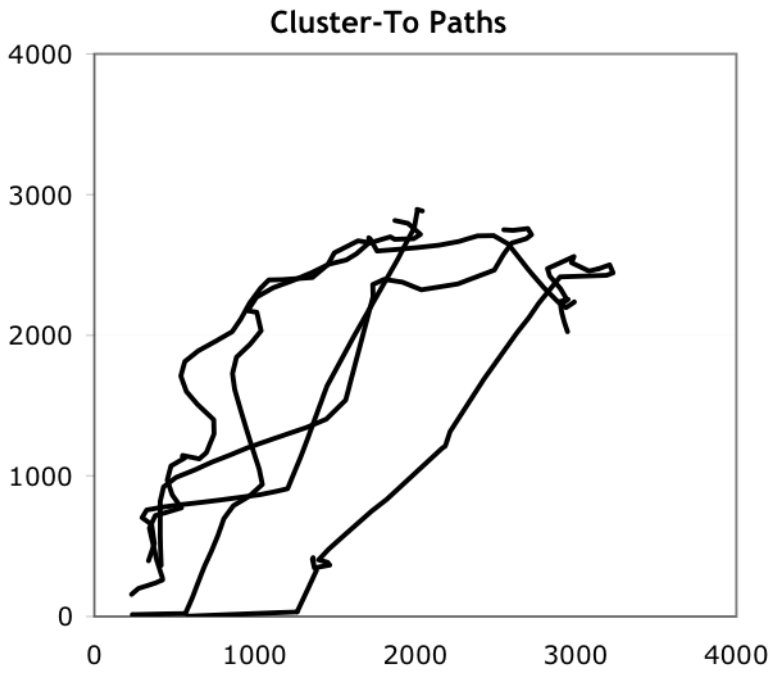
- Smoke test: distance-to

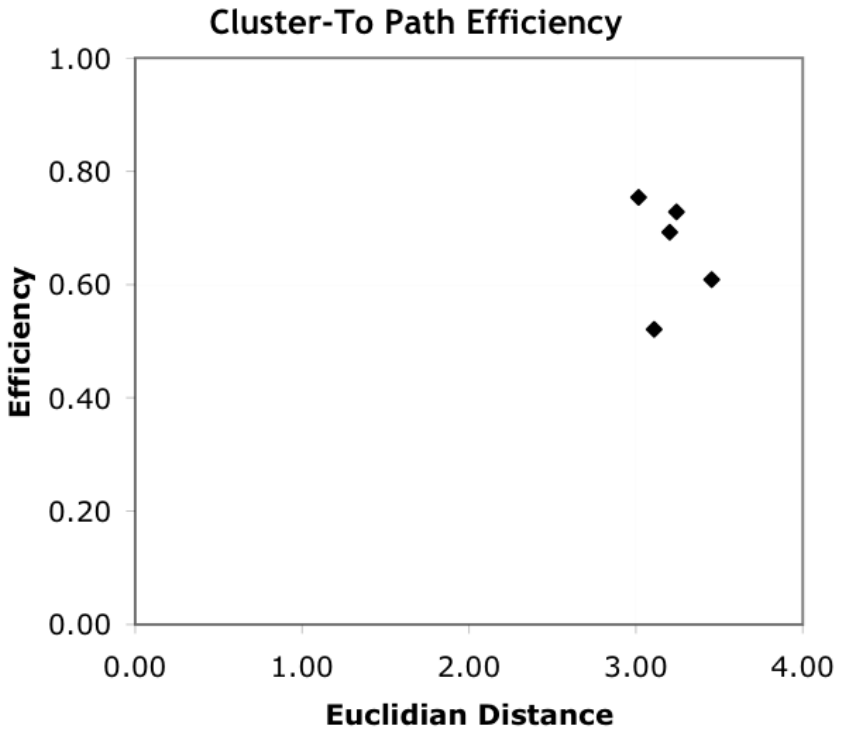
On McLurkin's SwarmBots



- Adaptivity to motion: dilate

On McLurkin's SwarmBots



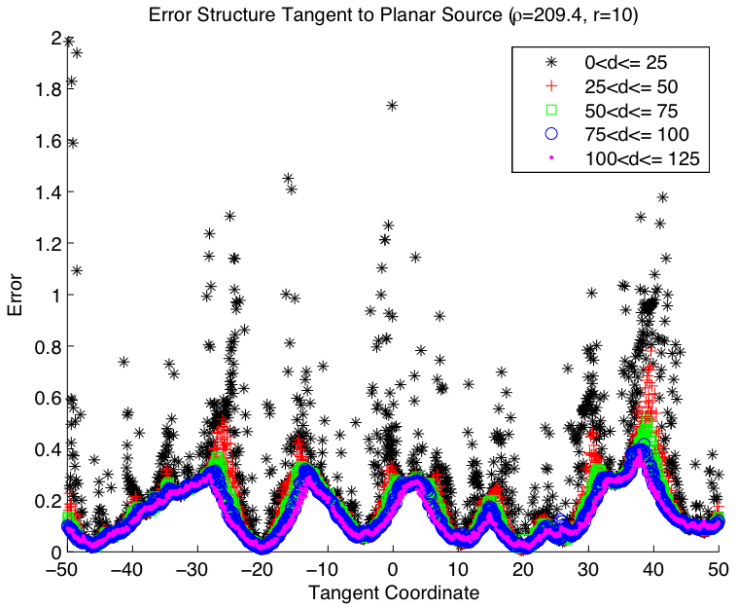


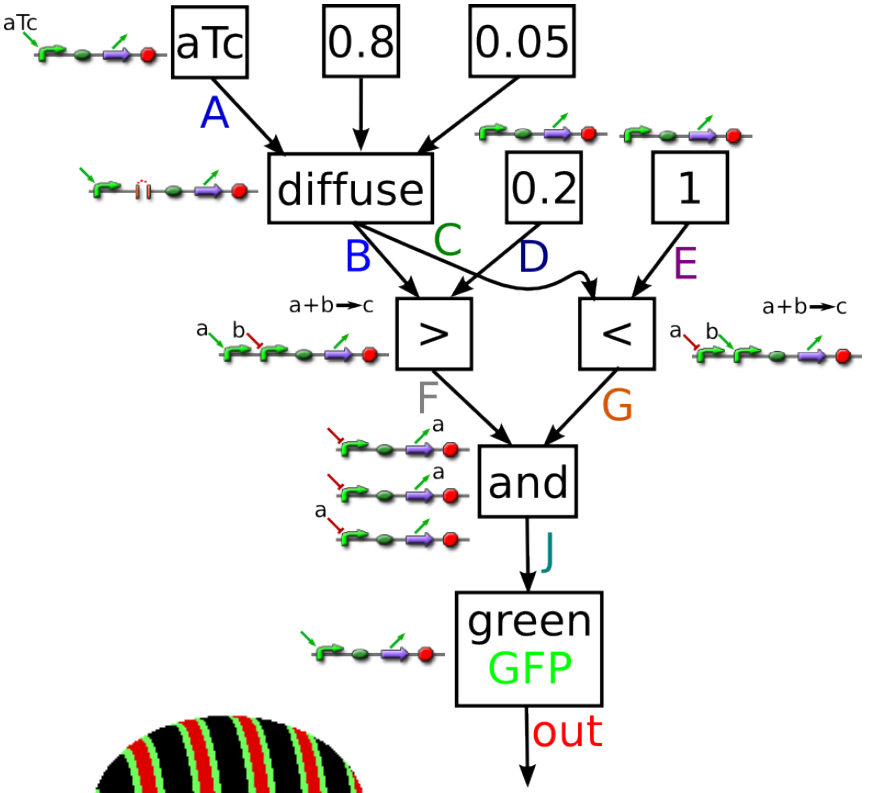
- Vector control of motion: cluster-to

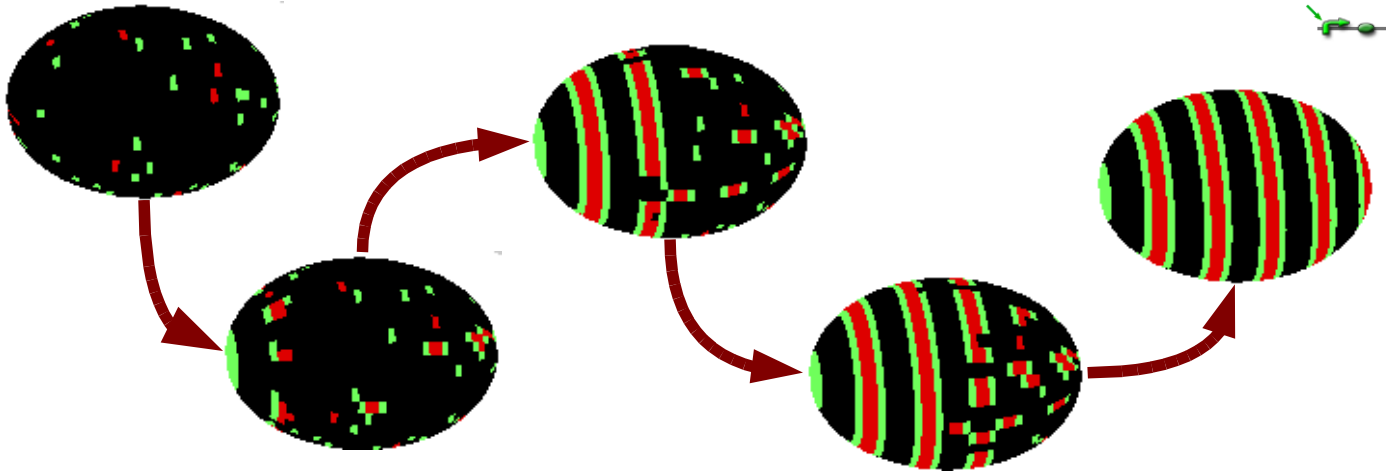
Summary

- Density of amorphous medium abstracts device motion as continuous mass flow.
- Device behave like a solid, a liquid, or a gas, depending on how tightly they are packed.
- In the gaseous state, complex, heterogeneous robot motion can be computed as vector fields.
- Spatial computers are only practical when the devices can be maintained almost entirely without human intervention.

Tomorrow: Current Frontiers







Further Questions

- What is the best mapping between mass-flow and device motion?
- How literally can we take the solid/liquid/gas metaphor for mobile devices?
- How can a swarm stay safely connected while reconfiguring rapidly?