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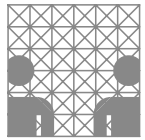

multi-agent robotic systems in logistics

a look at kiva systems and amazon robotics

robert a. brown

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Technische Aspekte Multimodaler Systeme

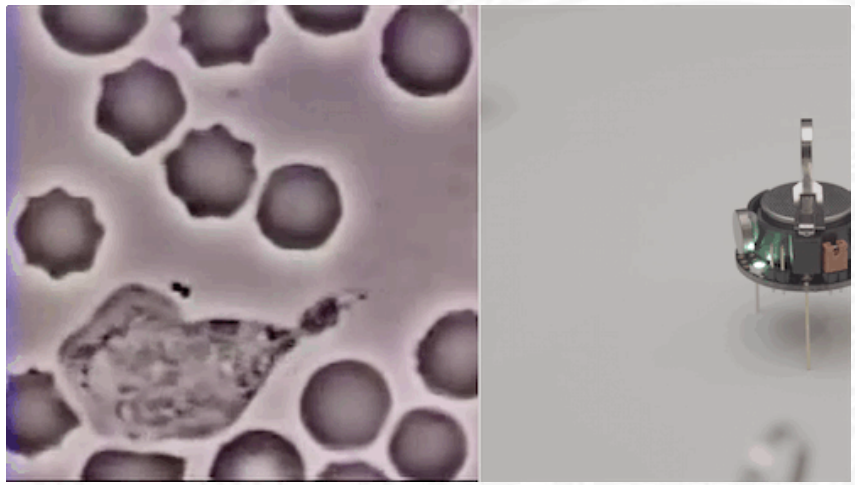
28. november 2016

What are Multi-Robotic Systems?

exactly what they sound like!

- coordination between large groups of relatively simple robots
  - working together towards common goal
  - not necessarily cooperative or communicative
  - local strategies
- draws inspiration from swarms found in nature
  - fish, birds, ants

- cooperative systems
  - communicate goals
- self-interested systems
  - compete for resources in market-based environment



[Loo15]

Can a thousand tiny swarming robots outsmart nature?

https://www.youtube.com/watch?v=dDsmbwOrHJs

Modeling Swarms

Brownian Motion as a PDE

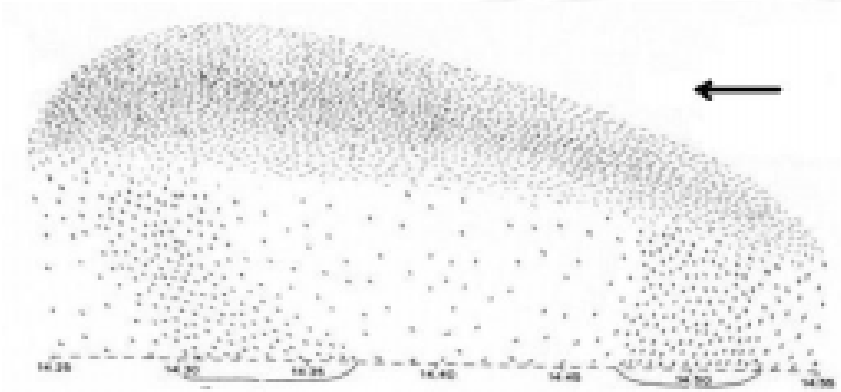
$$\frac{\partial p}{\partial t} = D\Delta p$$

$$\frac{\partial p}{\partial t} = \frac{v^2}{\mu}\left(\frac{\partial^2 p}{\partial x^2} + \frac{\partial^2 p}{\partial t^2}\right)$$

...with a Poison Process

$$\frac{\mu}{2} p_{tt} + p_{tt} = \frac{v^2}{\mu} p_{xx}$$

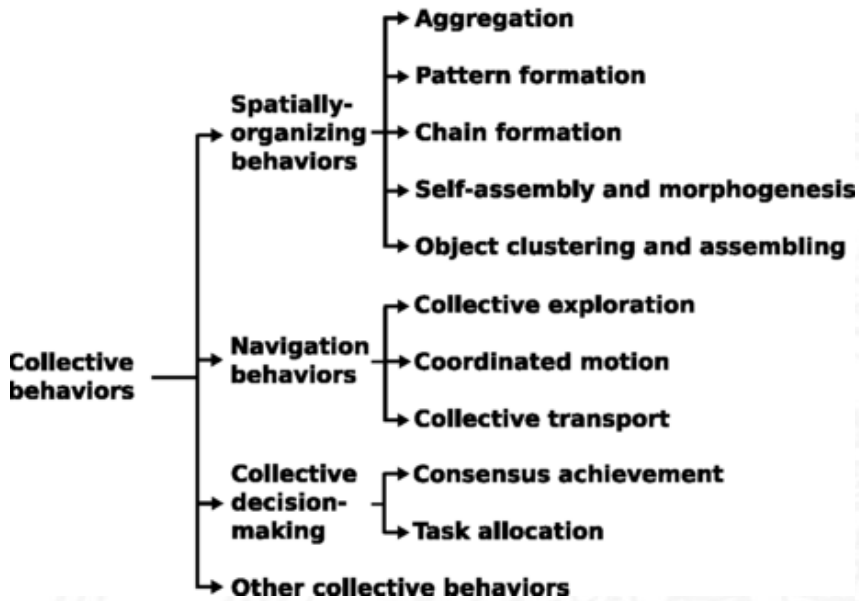
These types of complex systems composed of simple actors can be mmodeled as dynamic systems, and studying their interaction is a field unto itself...



Dynamic System Representing a Swarm of Locusts [Ek01]

What are Multi-Robotic Systems?

The group of robots is not just a group. It has some special characteristics, which are found in swarms of insects, that is, decentralised control, lack of synchronisation, simple and Identical Members [Ben05]



Taxonomies of Swarm Robotics [BFBD13]

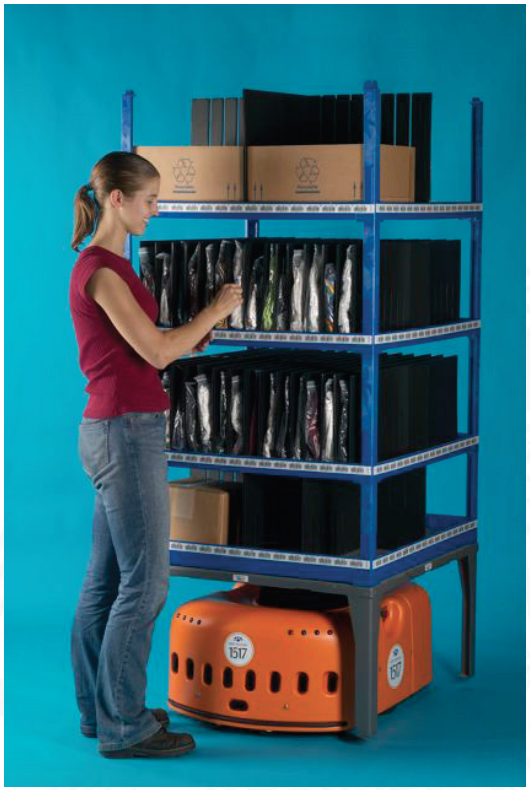
[Urd12]

Chaotic Storage

https://www.youtube.com/watch?v=ZxrzIXkPycs

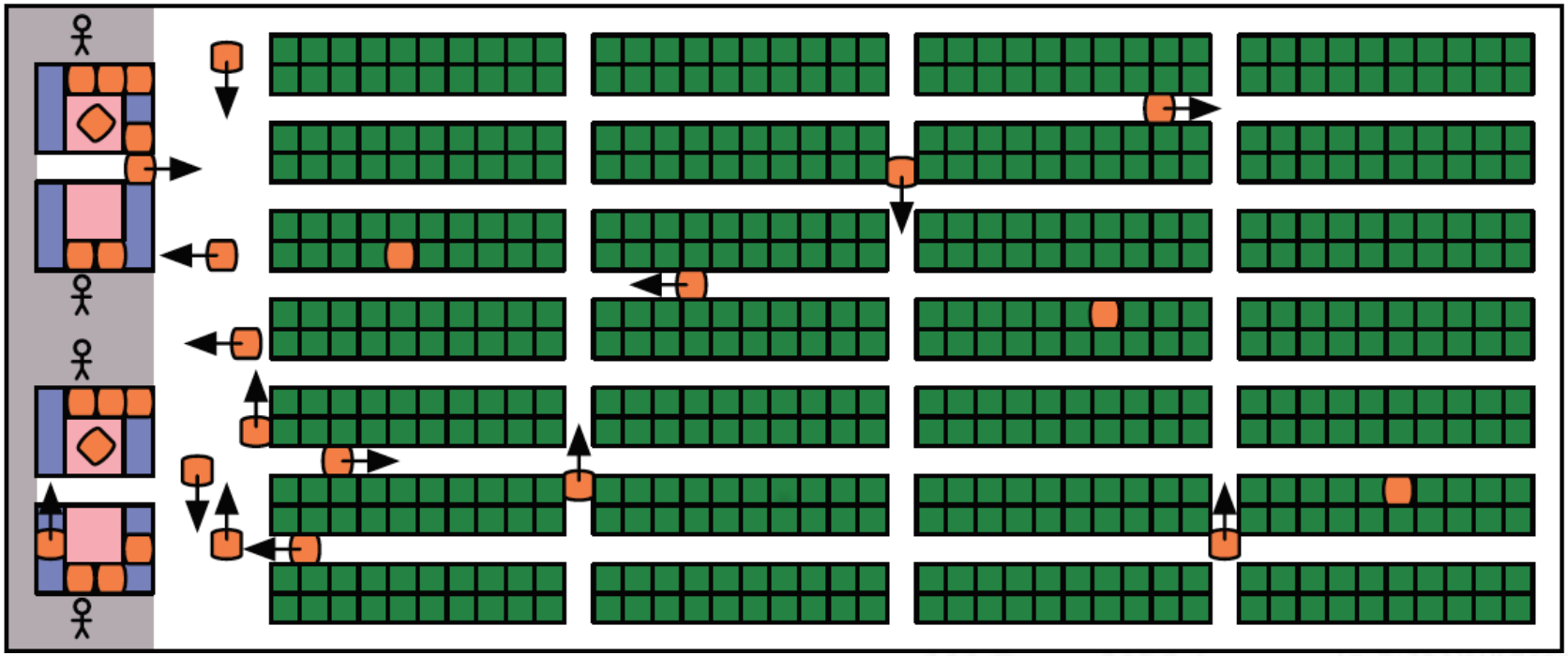
The Kiva Warehouse

- Rack
  - organized using chaotic storage
  - storage unit
- Robotic Agent ("Driver")
  - brings Racks to the Picker
  - returns rack to floor
- Picker
  - No longer fetches products



Example of a Kiva Systems Rack, Driver, and Picker [WDM07]

The Kiva Warehouse



Example of a Kiva Warehouse Floor Plan [WDM07]

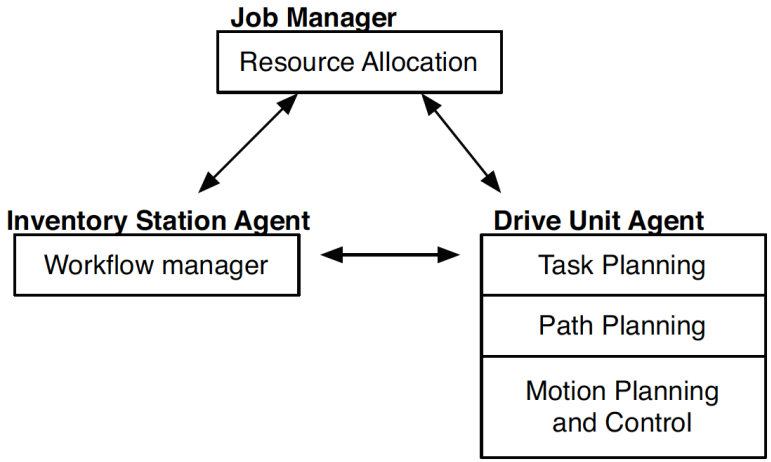
The Kiva Warehouse

https://www.youtube.com/watch?v=z_R8feyCu-M

Kiva Systems Software

what does the system need to do?

- actors must handle their own local tasks
- manage resources
  - space on racks
  - space on the floor
  - robot units
- manage task assignments



Interaction between layers of Kiva Warehouse [WDM07]

Kiva Systems Software

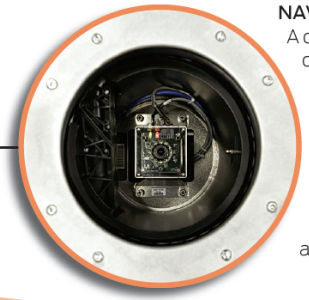
what do the actors need to do?

- find a path to the desired products
  - uses A* algorithm (simple, greedy, heuristic based "AI")
- navigate their environment
  - follows stickers on the floor
  - localization not needed
  - already knows map
- not hit each other

[Urb]

SQUAT AND SMART

Kiva's robots have more than 900 parts, from off-the-shelf dc motors to custom-made ball screws. Here's how the robots' main systems work. PHOTOS: JOSHUA DALSIMER



NAVIGATION SYSTEM
A camera facing upward reads bar codes placed under inventory racks to identify them. Another camera located at the bottom of the robot views bar codes on the floor. This location information is combined with readings from other navigation sensors, such as encoders, accelerometers, and rate gyros.

LIFTING MECHANISM
A large screw turns to raise racks of inventory 5 centimeters from the ground. At the same time, the wheels make the robot rotate in the opposite direction to keep the rack motionless.

POWER SYSTEM
Four lead-acid batteries power the motors and onboard electronics. When batteries run low, the robot automatically drives to a charging station.

COLLISION-DETECTION SYSTEM
Infrared sensors and touch-sensitive bumpers stop the robot if people or objects get in its way.

DRIVING SYSTEM
Two brushless dc motors control independent neoprene rubber wheels, moving the robot at 1.3 meters per second.

The Kiva Warehouse "Driver" [Gui08]

The Kiva Warehouse

Pros

- Greater accountability
- No single point of failure
- Optimization based on Popularity
- Rapid deployment
- Spatial flexibility
- Expandability

Cons

- Can't pick things up

Kiva Systems Software

https://www.youtube.com/watch?v=fwghi0jpKkYq

Conclusion

- Multi Agent Systems work independently to complete common goal
  - may or may not communicate
  - share resources
- Kiva systems uses MAS and surprisingly simple/primitive/old algorithms
  - real breakthrough was the idea (and cheaper robots)
- Kiva Warehouses store up to 200% storage capacity and productivity, as well as accountability [Gui08]

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