Communication of Swarm Robots

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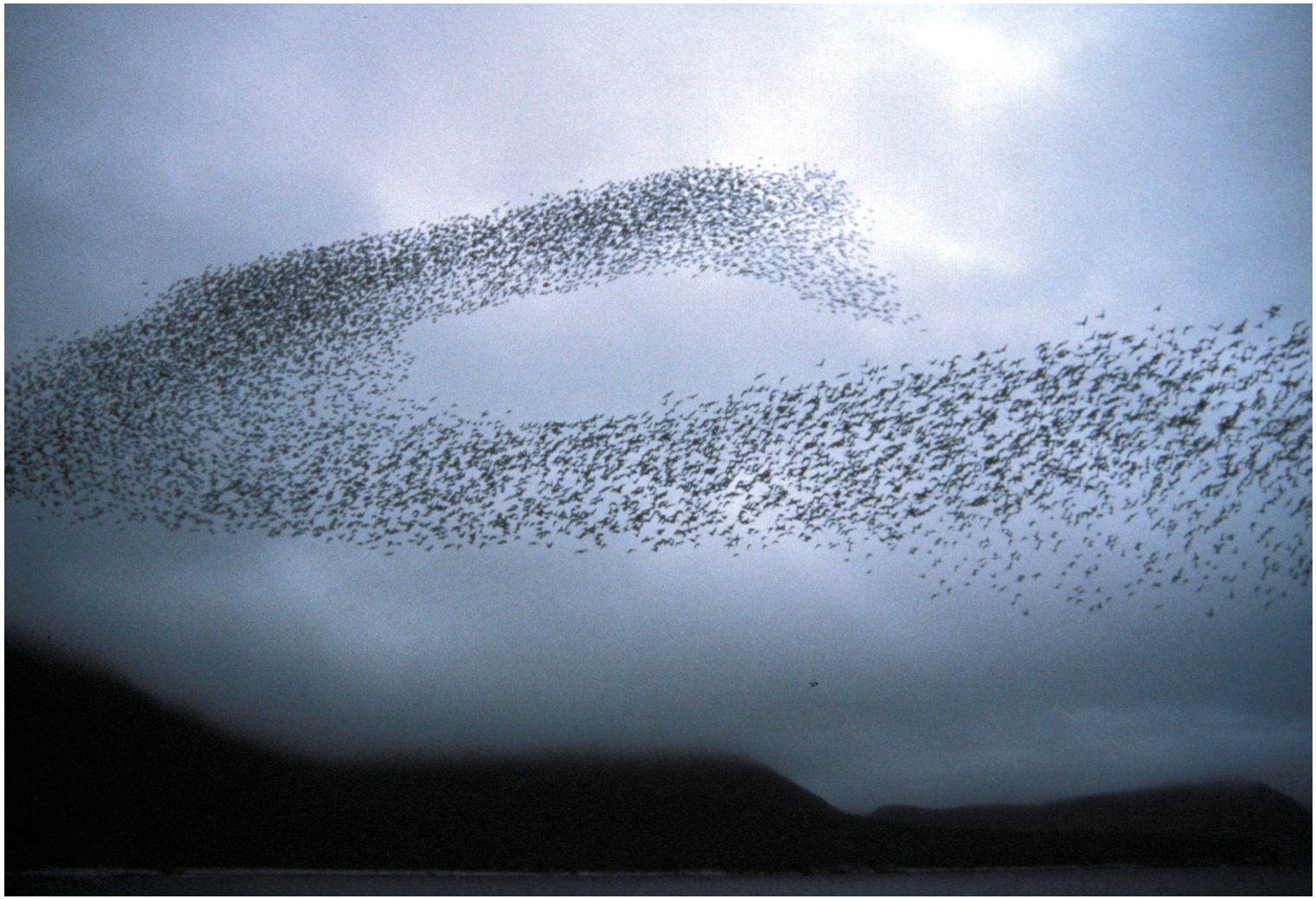
Contents

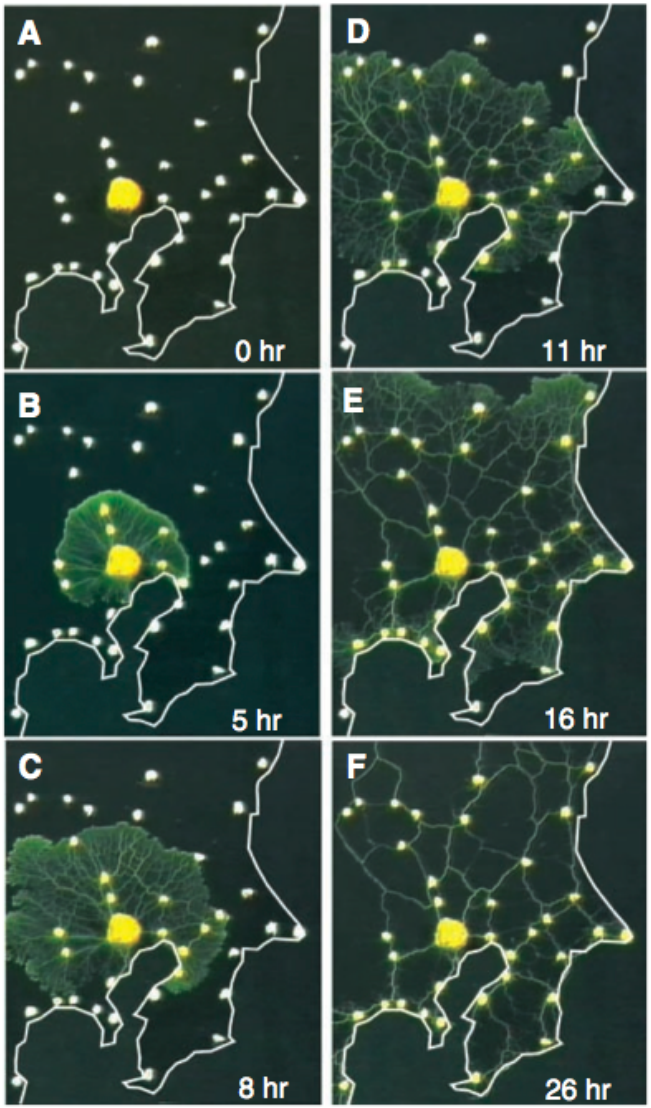
Swarms

- large numbers, scalability, fault tolerance
- coordination of large multirobot systems
- inspired by nature



(D. Dibenski, 1986)

(Mehmet Karatay, n.d.)



(Tero et al., 2010)

GUARDIANS: swarm robots to aid firefighters

(Witkowski et al., 2008) (Penders et al., 2007)
Scenario:

- fire in an industrial warehouse
- complex architecture
- metal and concrete walls
- toxic materials

The Swarm's Task

- aid the firefighters
- maintain a communication link
- detect humans
- locate danger: fire, smoke, toxic material

The Swarm's Task

- dynamic adhoc communication network
- positioning and mapping system
- toxic alarm system

Equipment

- WLAN, Bluetooth, ZigBee
- special sensors: temperature, gas
- SLAM
- mobility
- light, sound for communication with humans

Designing a Swarming Algorithm

- Situation: burning warehouse, lots of robots
- Task: search for hazards
- Problem: efficiently search and disperse to cover a large area

Designing a Swarming Algorithm

- centralised
- leader based
- behaviour based
- virtual structure
- learning based
- spring based models
- $\rightsquigarrow$social potential fields (Reif and Wang, 1999)

Social Potential Field

- every robot has a goal $\overrightarrow{EA}$
- obstacles to avoid $\sum \overrightarrow{ER}$
- wants to stay in contact with the other robots $\sum \overrightarrow{IA}$
- but also doesn't want to come to close $\sum \overrightarrow{IR}$

$$F = \overrightarrow{EA} + \sum_{\text{obstacles}} \overrightarrow{ER} + \sum_{\text{other robots}} (\overrightarrow{IA} + \overrightarrow{IR})$$

Social Potential Field

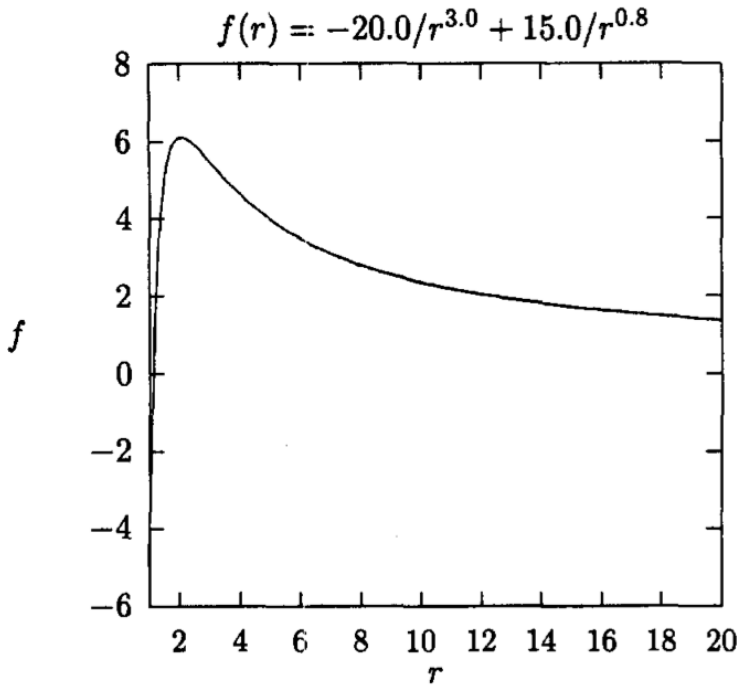
$$F_{i,j} = f(\|x_j - x_i\|)\frac{x_j - x_i}{\|x_j - x_i\|}$$

choose for example

$$f(r) = -\frac{c_1}{r^{\sigma_1}} + \frac{c_2}{r^{\sigma_2}}$$

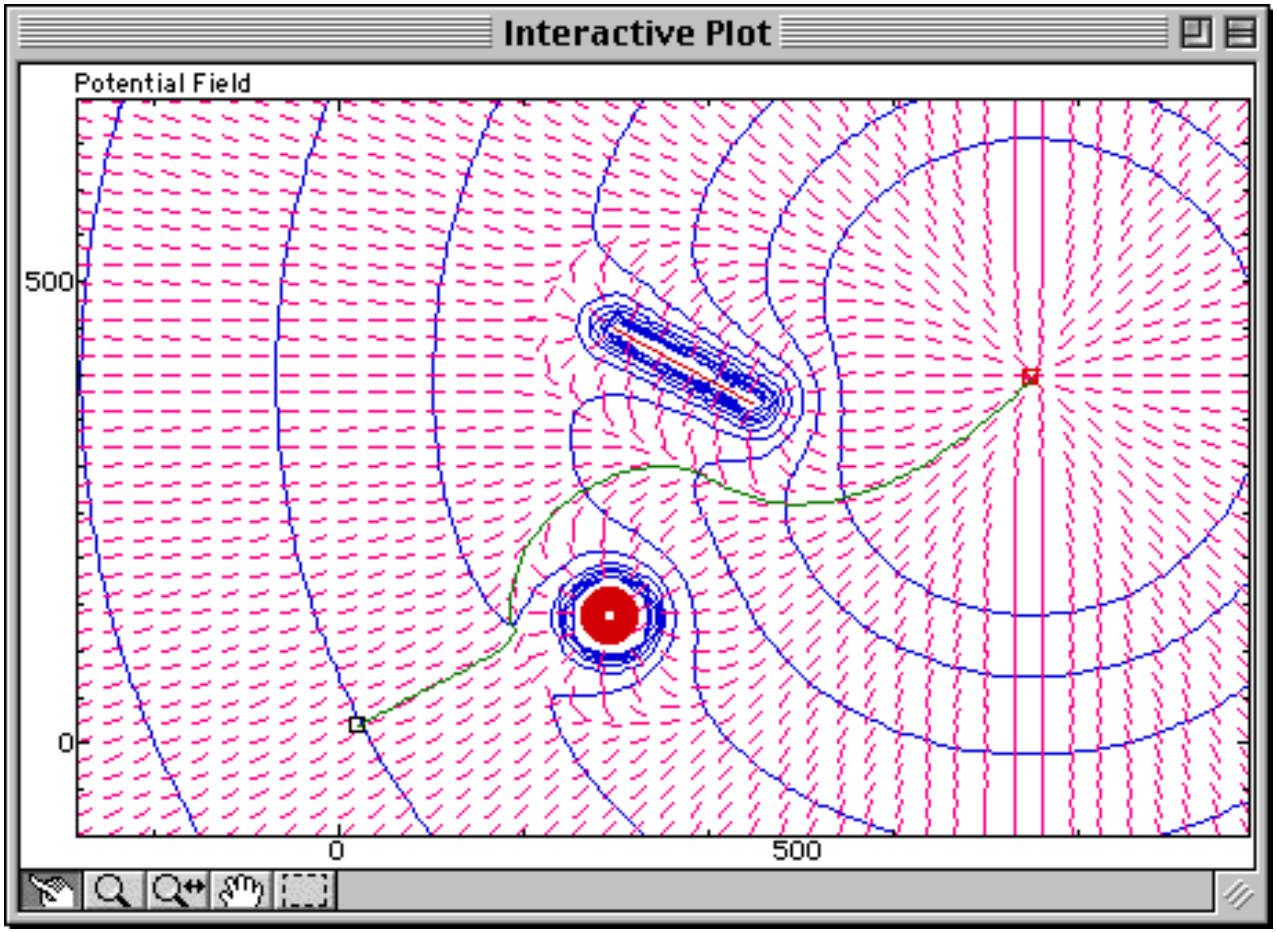
with $c_1, c_2 \geq 0 \ \wedge \ \sigma_1 > \sigma_2 > 0$

A Typical Potential Function



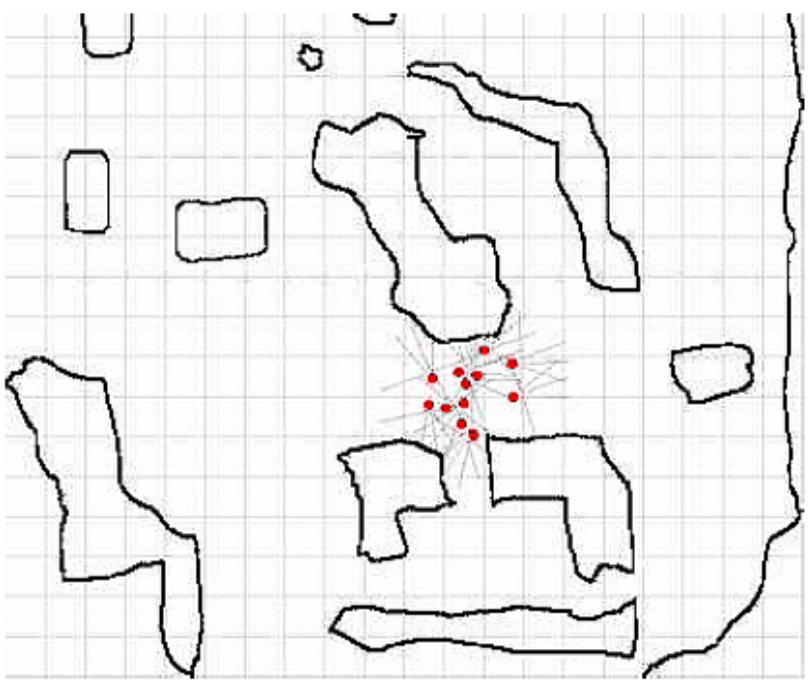
(Reif and Wang, 1999)

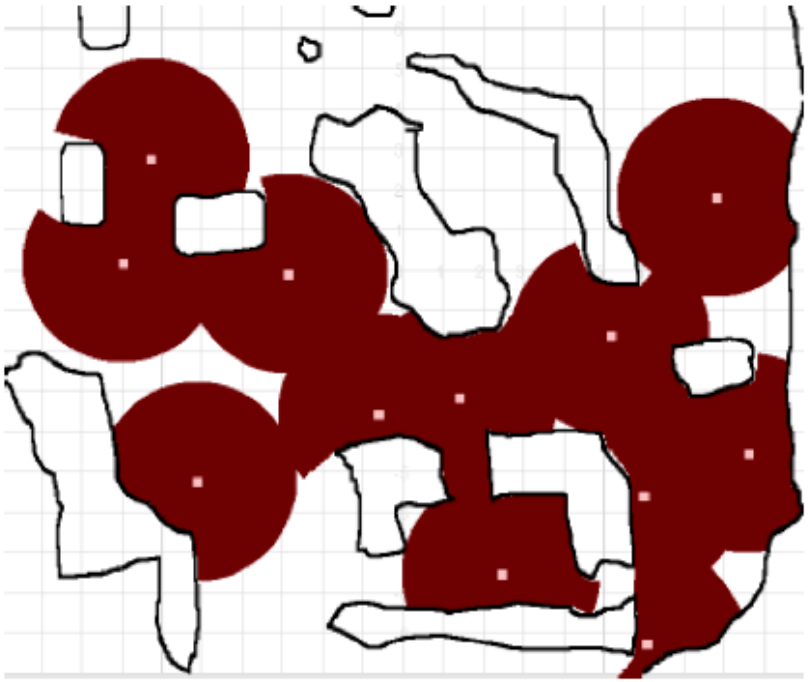
Example



(Calerga Sarl, n.d.)

Example





(Damer et al., 2006)

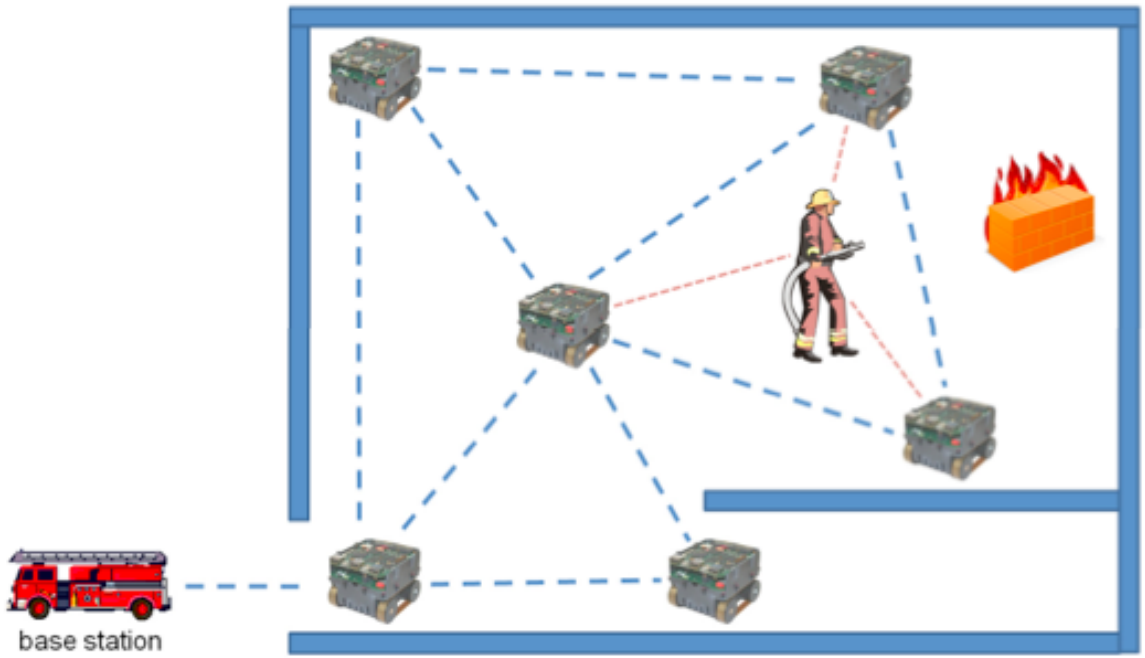
Advantages

- high level
- distributed
- still works with limited communication
- grouping possible
- analytical solutions

Additional Behaviour

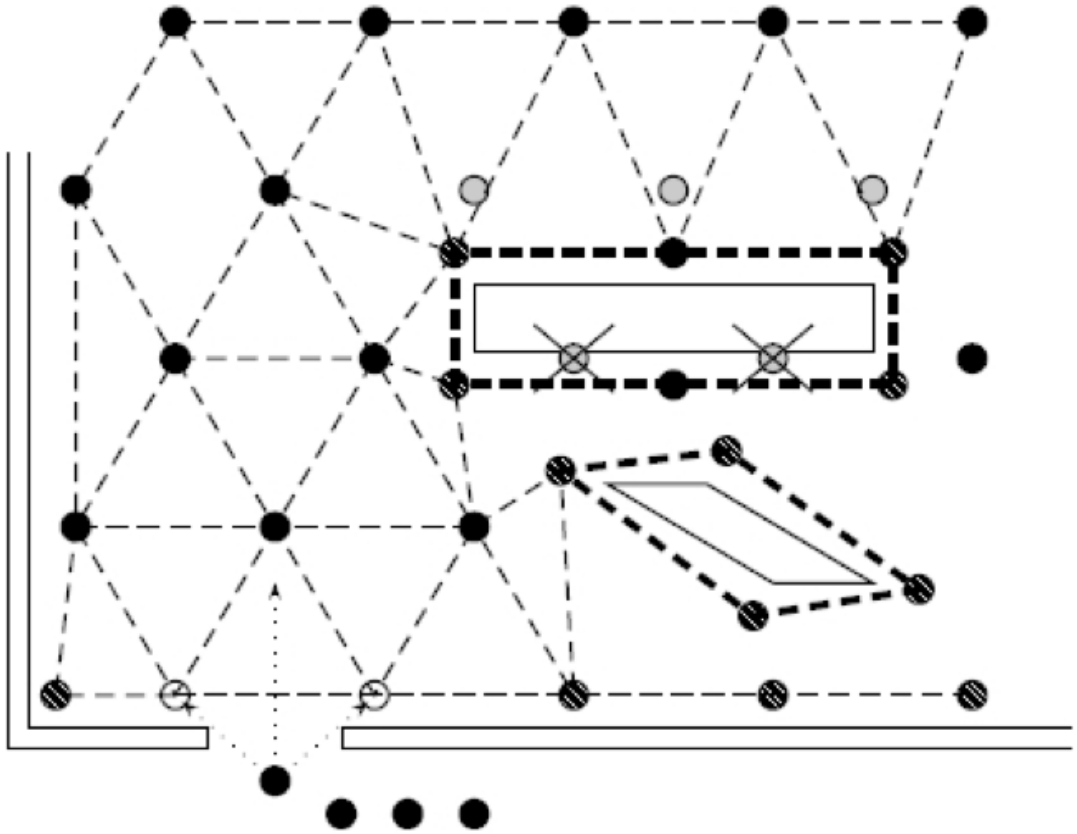
- Problem: swarm found something, how does it communicate it to the base station?
- $\rightsquigarrow$ build a communication network
- static beacon robots
- communication and localisation
- swarming algorithm to dynamically build the network topology

Dynamic Triangulation Method



(Witkowski et al., 2008)

Dynamic Triangulation Method



(Witkowski et al., 2008)

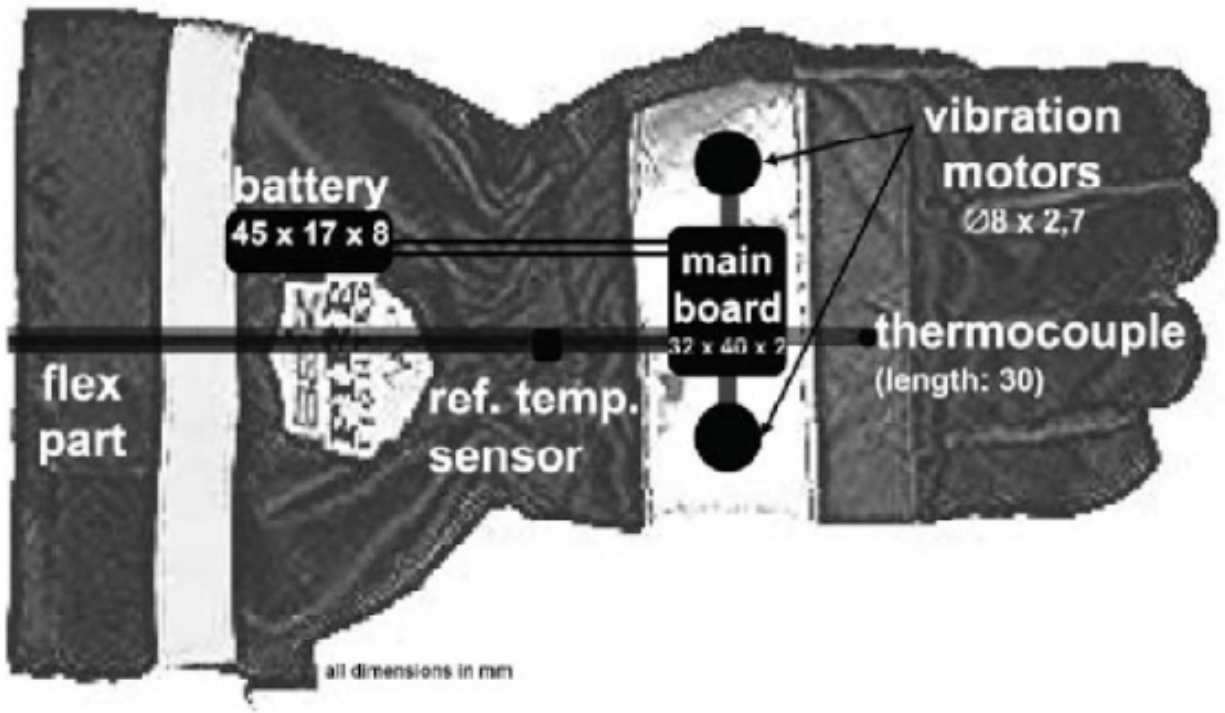
Communicative Swarming

- the global communication enables communicative swarming
- i.e. each robot can use global information to calculate its social potential field
- this also enables more effective division of labour
- grouping the robots with different social potential functions

Human-Robot Interaction

- the swarm provides a danger map at the base station
- the firefighter in the warehouse needs to command the swarm
- for example by applying a new potential, i.e. a new goal, a safe route
- robots needs to show the human potential hazards, paths . . .

UI



(Christof et al., 2010)

Conclusion

- a swarm can achieve more than a single actor
- distributed swarm algorithms are needed to control it as micromanaging is not feasible
- this is really complex
- but the control models can help by simplifying the problem
- interaction with and control by humans must also be considered

Citations I

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