Subsumption Architecture in Swarm Robotics

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Motivation

Swarm robotics, motivated by collective behaviours of biology swarm, has desirable properties

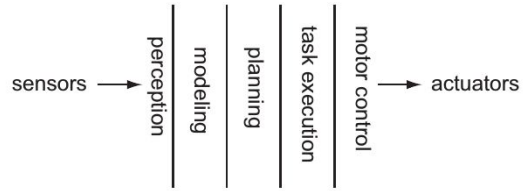
Effective approach for robot control architecture which emphasize emergence of behaviour from individual interactions

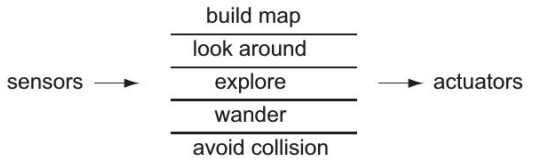
Subsumption Architecture Background

Developed by Rodney Brooks at MIT in mid 80s

Brooks argued that **Sense-Plan-Act** paradigm in traditional approach is not practical

Brooks suggested layered control system in horizontal decomposition





Bio-inspired Artificial Intelligence: Theories, Methods and Technologies. Chapter 6. Figure 6.4. Figure 6.5.

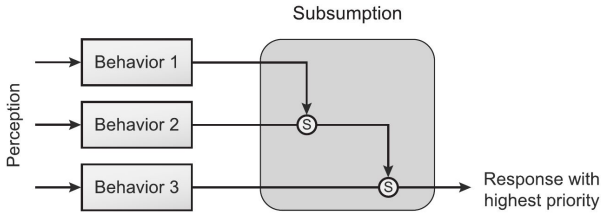
Subsumption Architecture Decomposition

Traditional approach:

- **Sense-Plan-Act (SPA)** approach

Subsumption architecture:

- Inherent parallel system

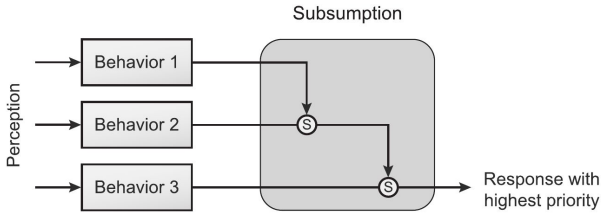


Bio-inspired Artificial Intelligence: Theories, Methods and Technologies. Chapter 6. Figure 6.7 a)

Subsumption Architecture Decomposition (cont.)

Layers of behaviour:

- Each layer is a pre-wired behaviour
- Higher level build upon lower level for complex behaviours
- The layers operate asynchronously



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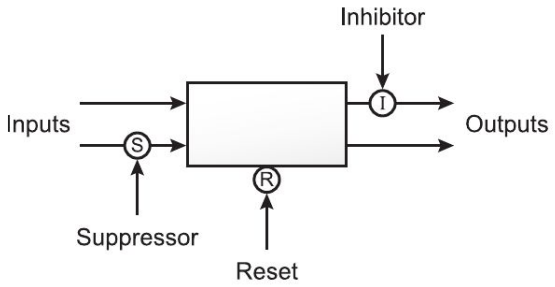
Subsumption Architecture
Behaviour module

Higher behavioural module subsume the competence of lower behavioural module

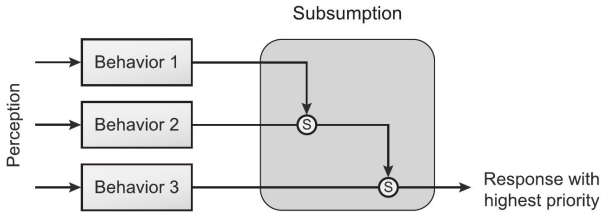


Bio-inspired Artificial Intelligence: Theories, Methods and Technologies. Chapter 6. Figure 6.6

Subsumption Architecture Features

Key features:

- No knowledge representation or world model is used.
- The behaviours are organized in bottom up fashion
- Complex behaviour are fashioned from combination of simpler ones



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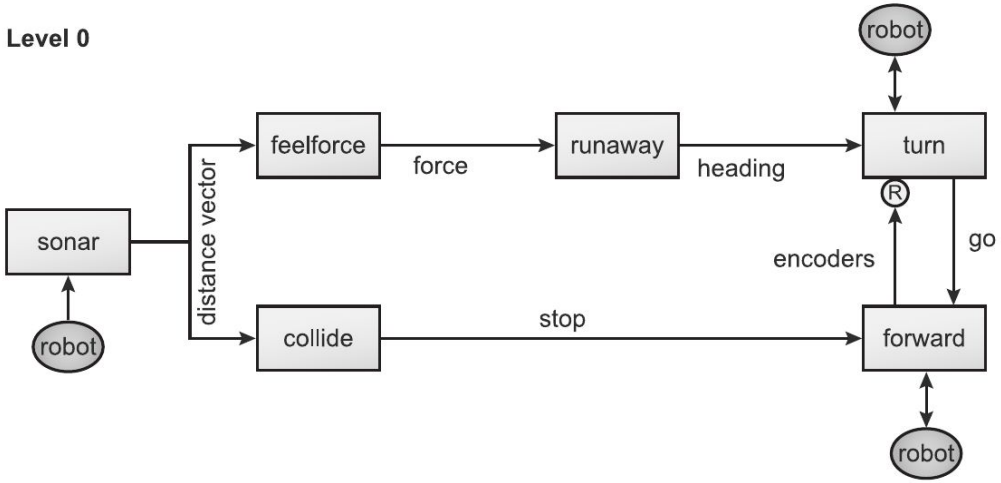
Subsumption Architecture Implementation

Navigation of a mobile robot

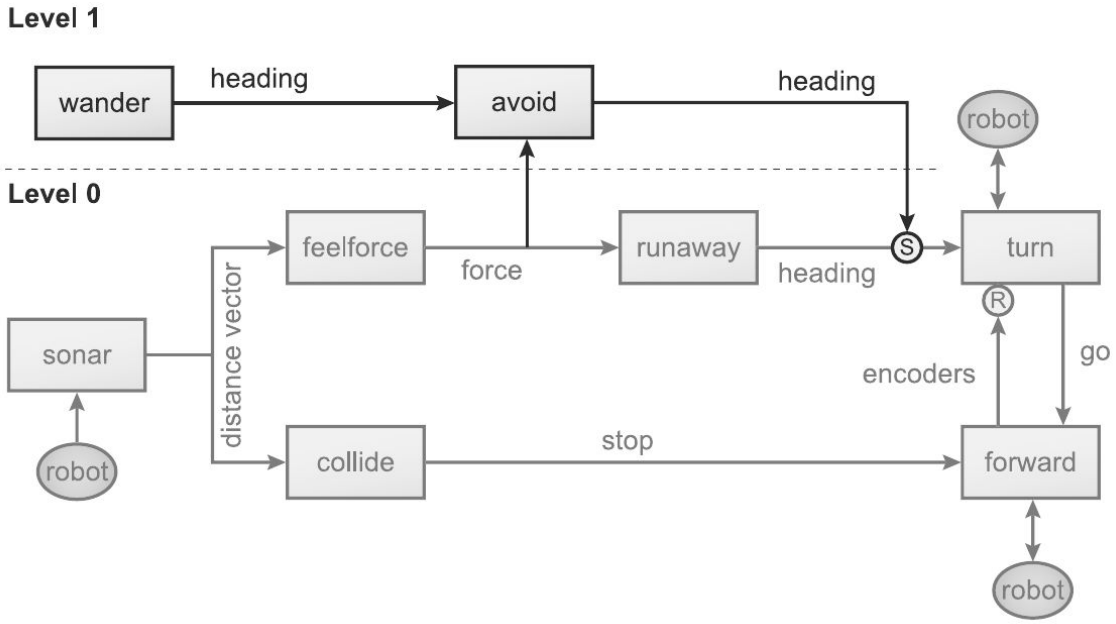
- An example from Brook (1986)
- Robot is a wheeled platform with circular array of sonar sensor

Subsumption Architecture Implementation (cont.)



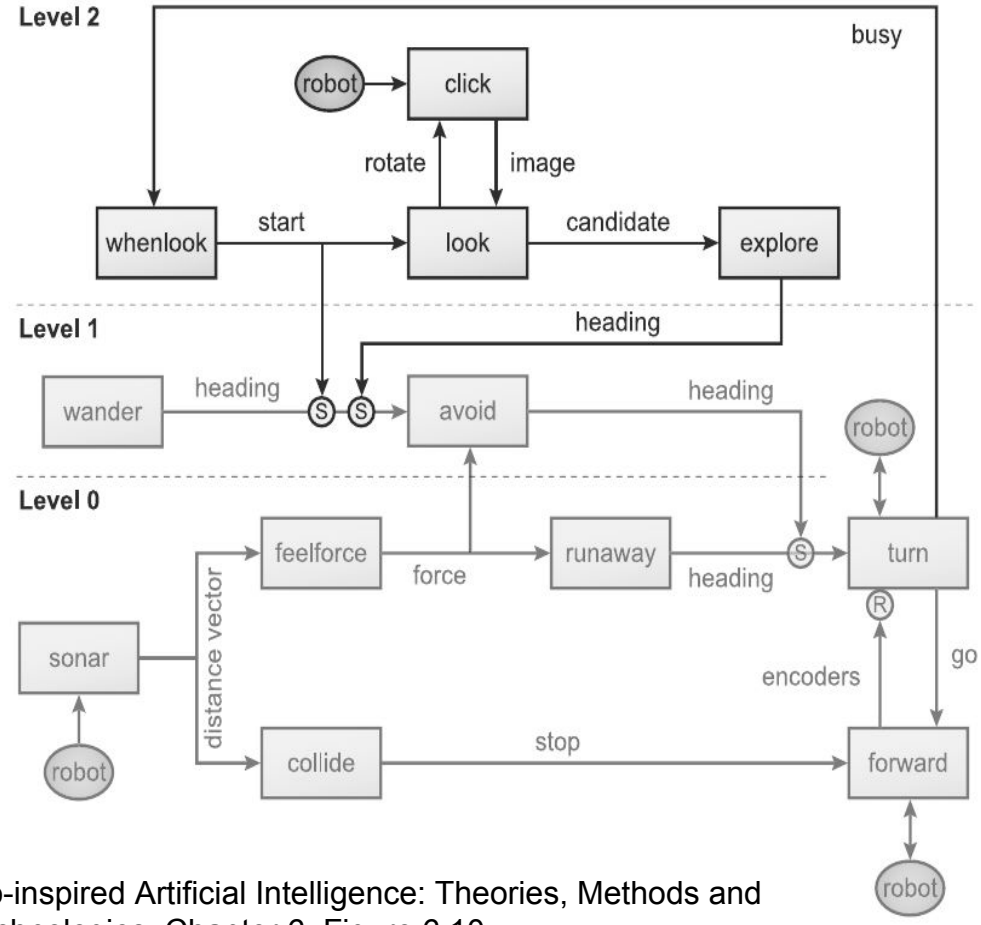
Bio-inspired Artificial Intelligence: Theories, Methods and Technologies. Chapter 6. Figure 6.8.

Subsumption Architecture Implementation (cont.)



Bio-inspired Artificial Intelligence: Theories, Methods and Technologies. Chapter 6. Figure 6.9.

Subsumption Architecture Implementation (cont.)



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Subsumption Architecture Evaluation

Strength

- Reactivity
- Parallelism
- Incremental design

Weakness

- Inflexibility at runtime
- No explicit representation of knowledge

Swarm Robotics
Swarm intelligence

Studies of large collection of simple agents which can collectively solve problems that are too complex for a single agent

Example:

- Particle Swarm Optimization
- Ant colony optimization

http://cir.institute/wp-content/uploads/2014/09/birds_vortex_800x450.jpg

Swarm Robotics Definition

Simple interaction among robots in order to solve complex problem

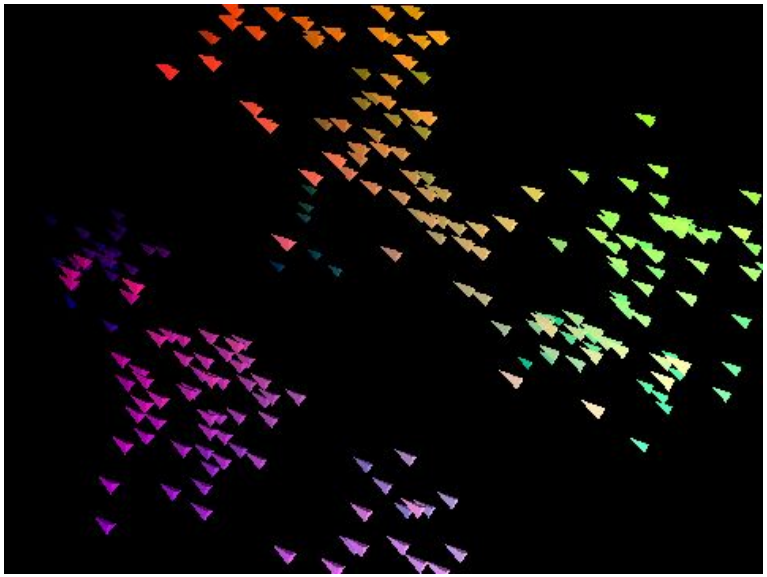
Group of 10 to 100 units

http://singularityhub.com/wp-content/uploads/2009/06/swarm-robots.jpg

Swarm Robotics Advantages

Potential advantages

- Robustness
- Flexibility
- Scalability



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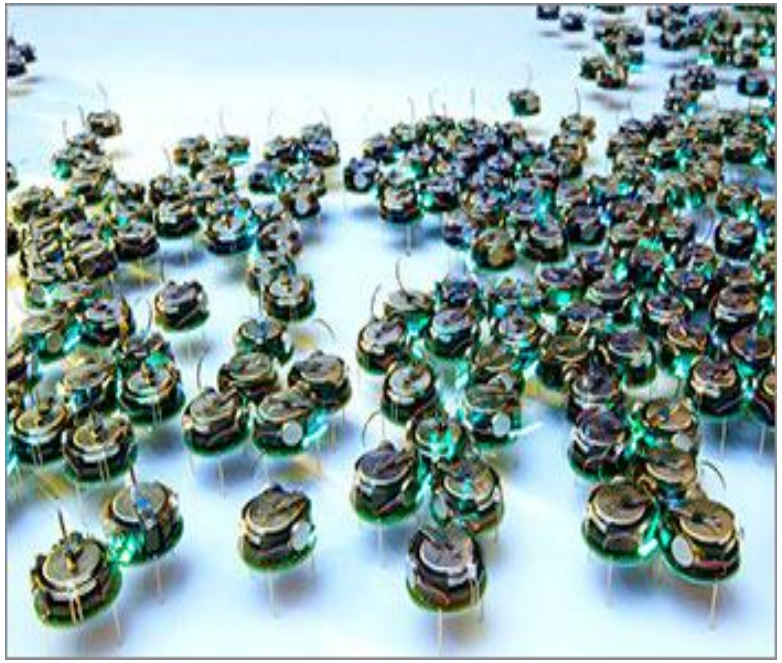
Swarm Robotics Classes



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Swarm Robotics
Control architecture

The process of perceiving environment, reasoning and acting is defined by the robot's control architecture

Behaviour-based control is often used

- Methodology for adding and fine-tuning control
- Distributed and asynchronous robots without central control

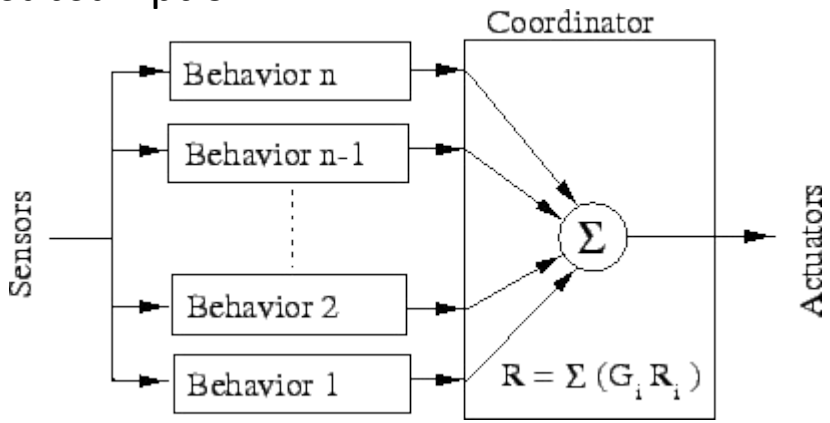
Swarm Robotics
Case study 1

Autonomous robots perform underwater mine countermeasures (UMCM)

Two behaviour-based architectures were used for testing and implementation: subsumption and motor schema

Behaviour

- Avoiding mines
- Avoiding obstacles
- Aggregation_Seperation



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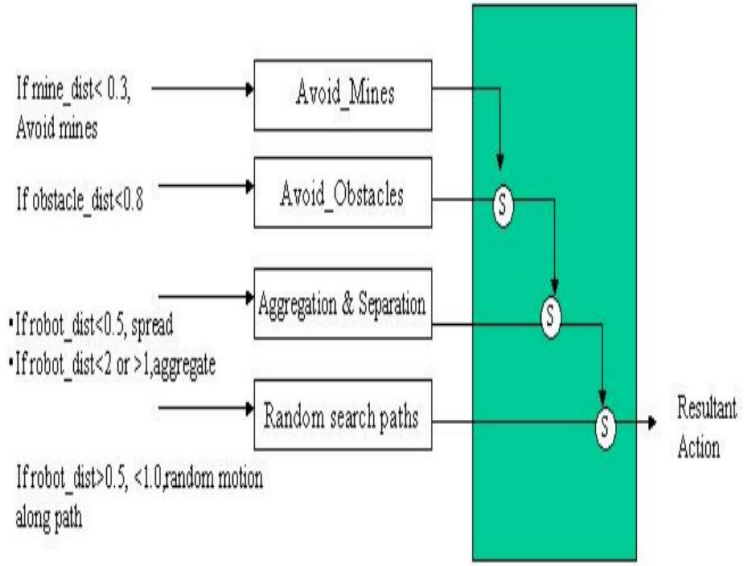
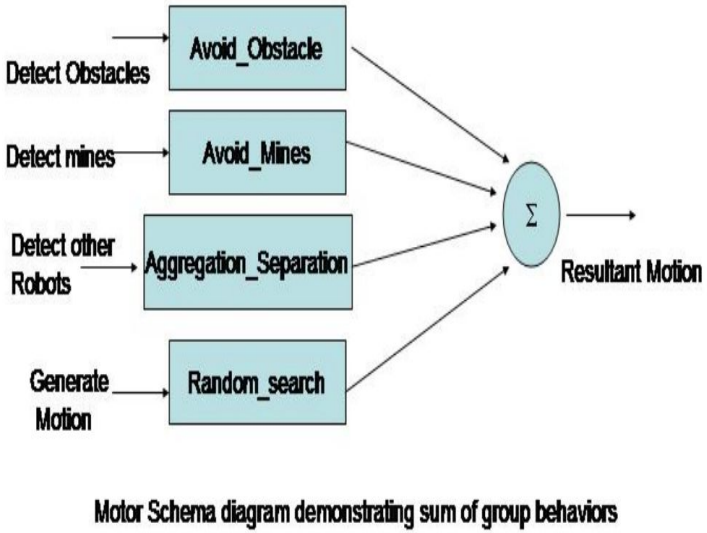
Swarm Robotics
Case study 1 (cont.)



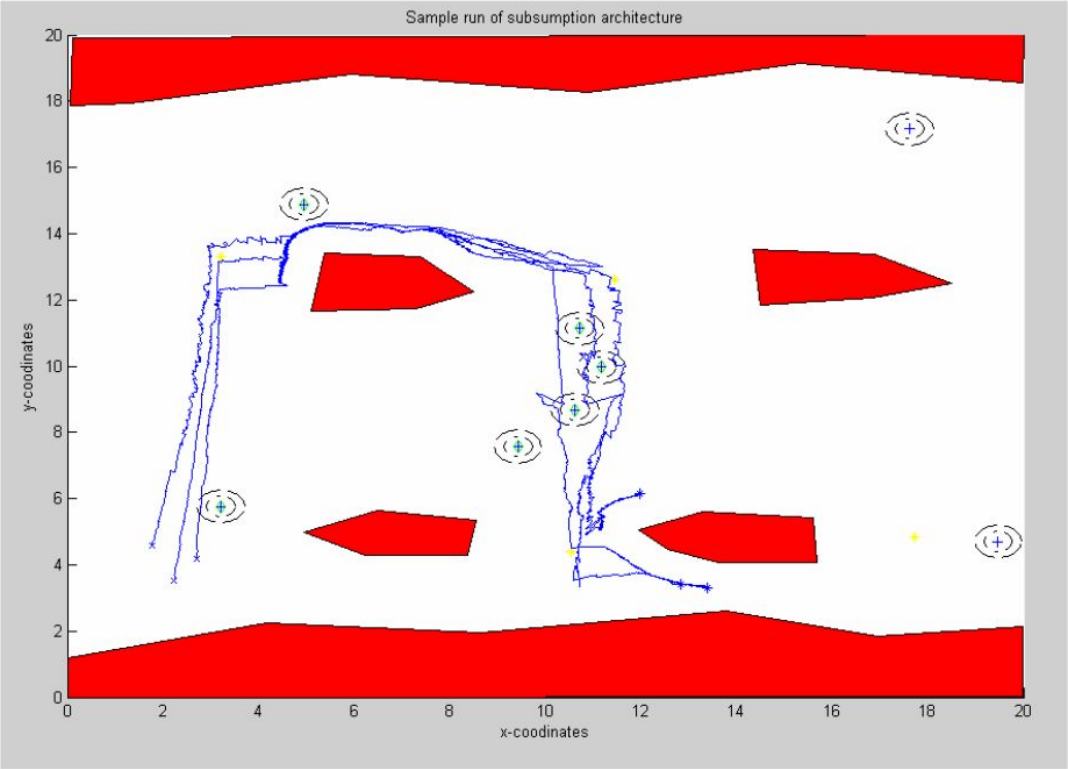
[2]. Figure 20. Subsumption architecture of a mine hunting robot



Motor Schema diagram demonstrating sum of group behaviors

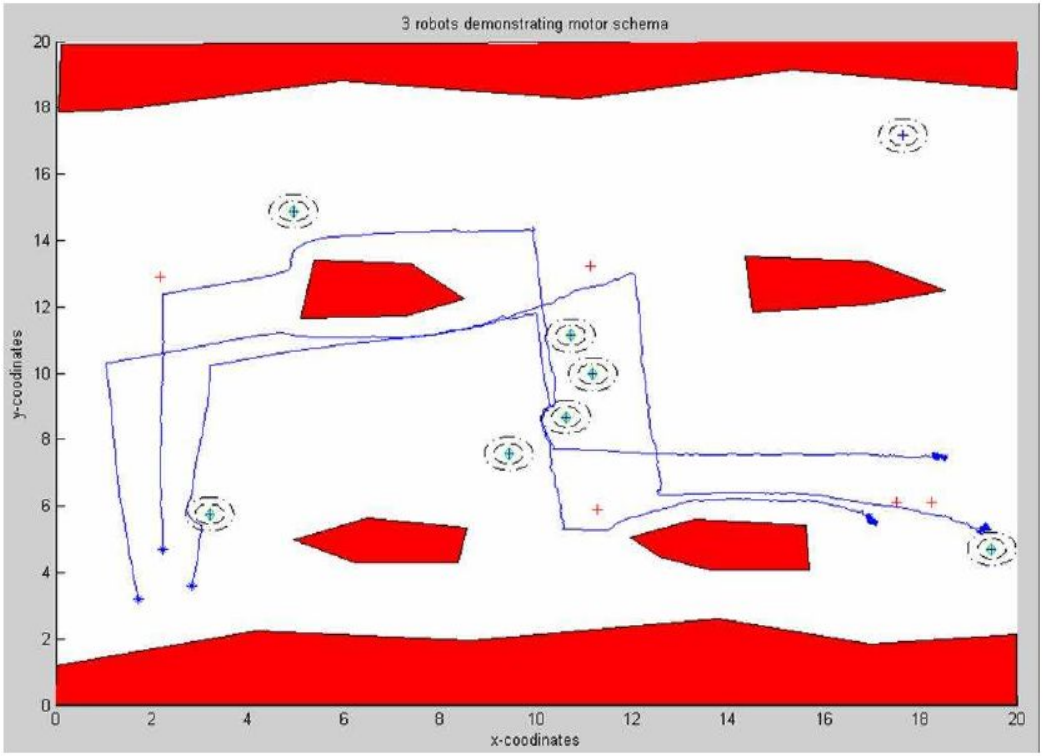
[2]. Figure 3. Motor schema architecture for mine hunting

Swarm Robotics
Case study 1 (cont.)



[2] Figure 21. 3 robots performing UMCM under subsumption architecture

Swarm Robotics
Case study 1 (cont.)



[2] Figure 18. Robot swarm performing UMCM with motor schema

Swarm Robotics
Case study 1 (cont.)

Subsumption Architecture

+ Decision structure to pick correct behaviour
+ Reactive to the environment

- Inconsistent formation
- Unpredictability - may suffer from chaotic instability

Motor schema

+ Individual behaviour modular in nature
+ Effective in controlling motion of individual robots

- Lack of decision structure

Swarm Robotics
Case study 1 (cont.)

The motor schema approach is effective for controlling the motion of individual robots with a swarm

The subsumption approach shows poor aptitude for swarm control. It lacks coordination except for collision avoidance

Swarm Robotics
Case study 2

Exploration and foraging task is noncooperative - could be performed by one robot

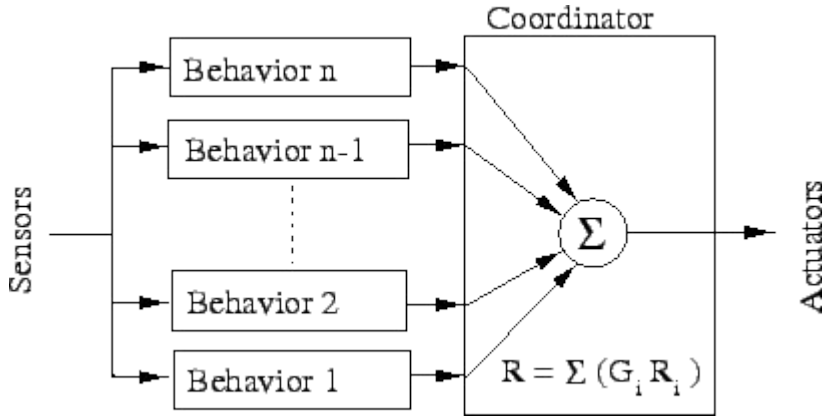
Box pushing task

- Robots cooperate in order to push a box to set location

Swarm Robotics
Case study 2 (cont.)

Hybrid control architecture

- Subsumption Architecture
- Motor schema Architecture



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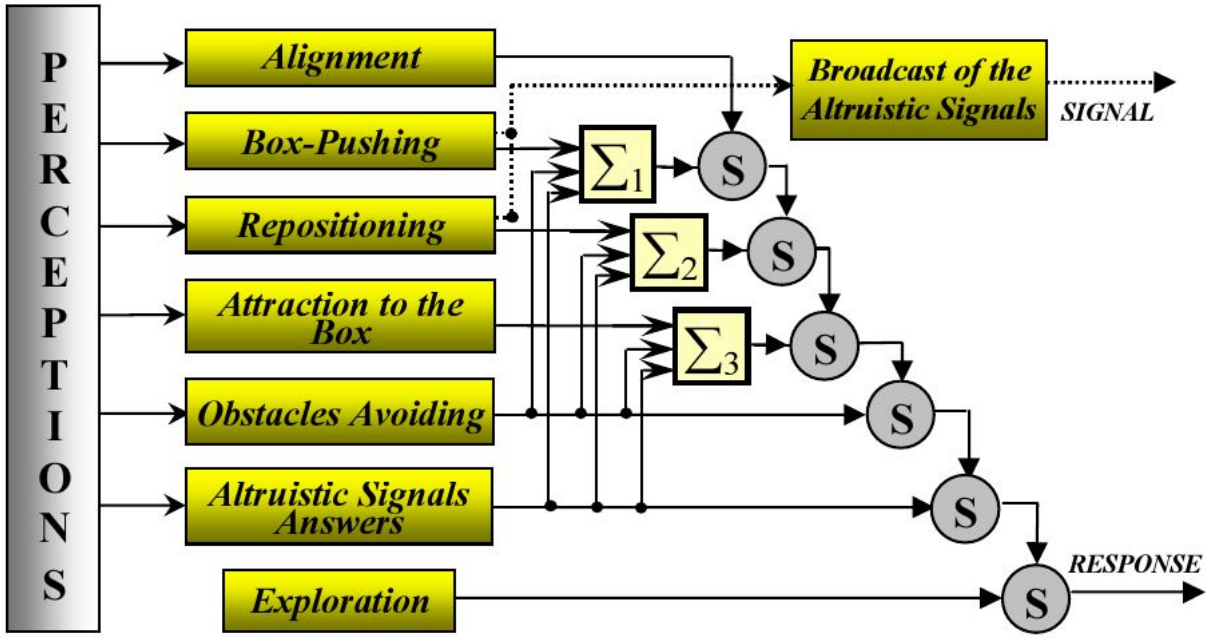
Swarm Robotics
Case study 2 (cont.)

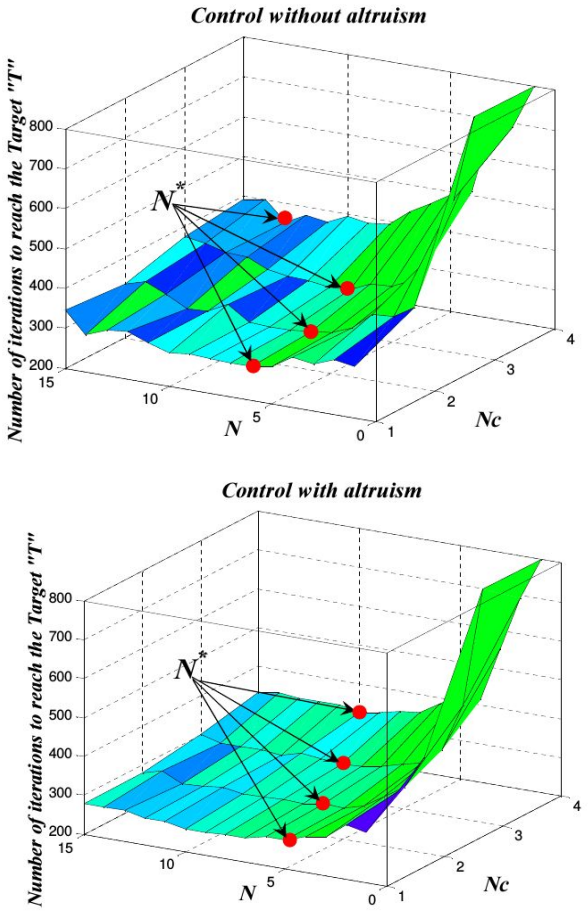


[4] Figure 2. Control based hybrid architecture

Swarm Robotics
Case study 2 (cont.)

The use of low-level communication give more coordination and robustness of interaction

The hybrid control architecture is very efficient in cooperative task



[4] Figure 8. Evolution of the number of iteration according to N and Nc

Conclusion

Subsumption Architecture yields great result - emergence of complex behaviours from simple ones.

Pure subsumption is inadequate in solving certain tasks.

Proposed hybrid architecture: cross subsumption, neural networks learning, global knowledge and planning

Reference

[1] Floreano, D., & Mattiussi, C. (2008). *Bio-inspired artificial intelligence: Theories, methods, and technologies*. Cambridge, Mass: MIT Press.

[2] Tan, Y.C. Synthesis of a controller for swarming robots performing underwater mine countermeasures. *U.S.N.A. Trident Scholar project report*; no.328, 2004.

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[3] Rodney A. Brooks. (1985). A Robust Layered Control System for a Mobile Robot. *Technical Report. Massachusetts Institute of Technology, Cambridge, MA, USA.*

[4] Adouane, L., Le Fort-Piat, N., "Hybrid behavioral control architecture for the cooperation of minimalist mobile robots," in *Robotics and Automation, 2004. Proceedings. ICRA '04. 2004 IEEE International Conference on* , vol.4, no., pp.3735-3740 Vol.4, April 26-May 1, 2004