The SWARM-BOTS project

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www.swarm-bots.org

Project funded by the Future and Emerging Technologies arm of the IST Programme FET-Open scheme - IST-2000-31010.

the SWARM-BOTS project:
General Information

- IST-2000-31010 (FET)
- Started on October 1st, 2001
- Lasts 42 months
- Budget: approx 2 millions EUR
- Web site: `www.swarm-bots.org`

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the SWARM-BOTS project:
General Purposes

- The SWARM-BOT project aims to study a novel **swarm robotics system**
  - It is directly inspired by the **collective behavior** of social insects and other animal societies
  - It focuses on **self-organization** and **self-assembling** of autonomous agents
  - Its main scientific challenge lays in the development of a **novel hardware** and of **innovative control solutions**

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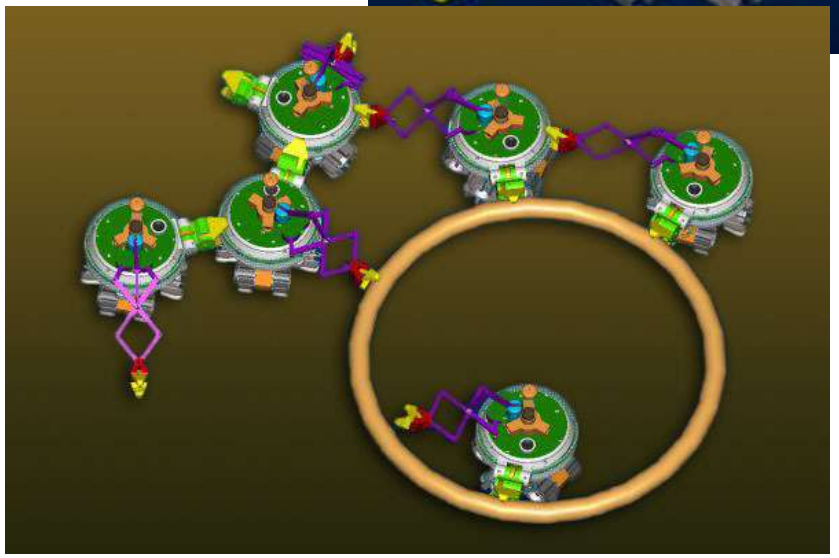
the SWARM-BOTS project:
s-bots and *swarm-bots*

- The elementary hardware unit is an **autonomous robot** called *s-bot*
- *S-bots* have **limited** individual capabilities, but they can **connect** to each other, forming a *swarm-bot*
- Exploiting the **cooperation** of its components, a *swarm-bot* can cope with problems that individual *s-bots* cannot solve



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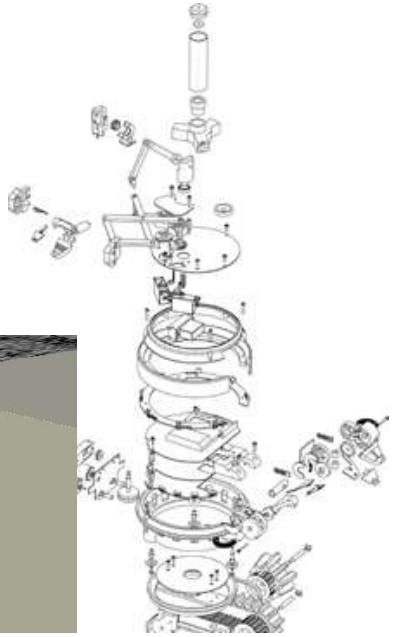
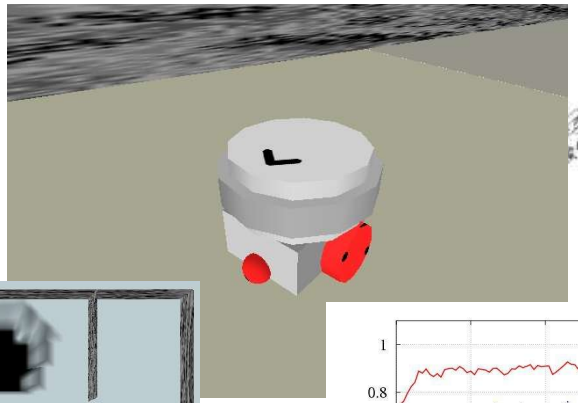
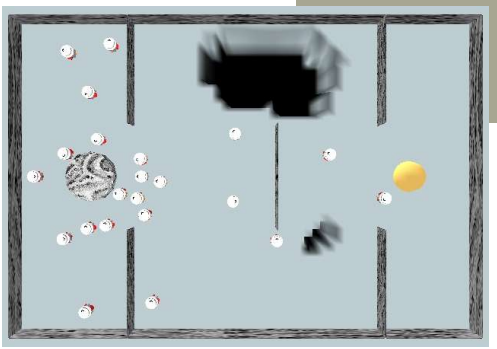
the SWARM-BOTS project:

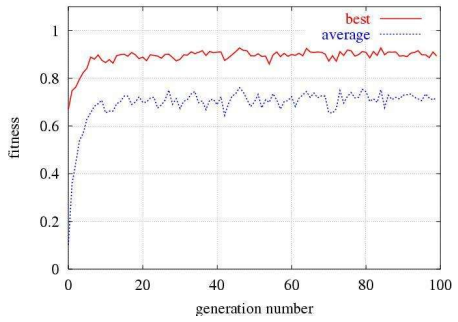
Layout of the Presentation

- Description of the hardware
- Brief overview of the simulation tool
- Control activities
  - Project scenario
  - Obtained results









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Hardware:
Innovative Features (1)

- Differential drive motion provided by both **tracks** and **wheels** (*Treels* ©)
- Turret **rotating** with respect to the chassis
- Two **connection** facilities
  - Rigid gripper
  - Flexible gripper
- Colored LEDs (**light ring**)

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Hardware:
Innovative Features (2)

- Many sensory systems
  - Proximity sensors
  - Ambient light sensors
  - Ground sensors
  - Light barrier in the grippers
  - Omni-directional camera
  - Sound signaling system
  - Traction and torque sensors
  - Humidity and temperature
  - 3-axis accelerometer

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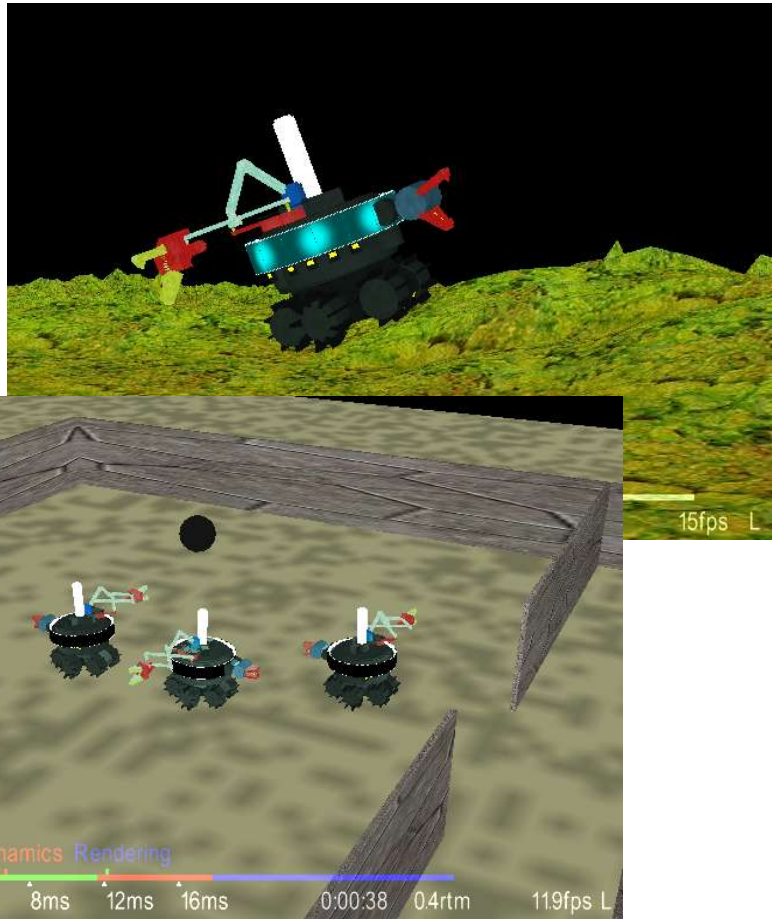
Simulation Features

- We developed a **3D Dynamics Simulator** (based on the Vortex™ SDK)
  - Detailed modeling of **mechanical parts**
  - Precise simulation of rigid body **dynamics** and **collision**
- Modular implementation
- Multi-robot handling facilities
- Simulated sensor have been **characterized** and **compared** using the real robot



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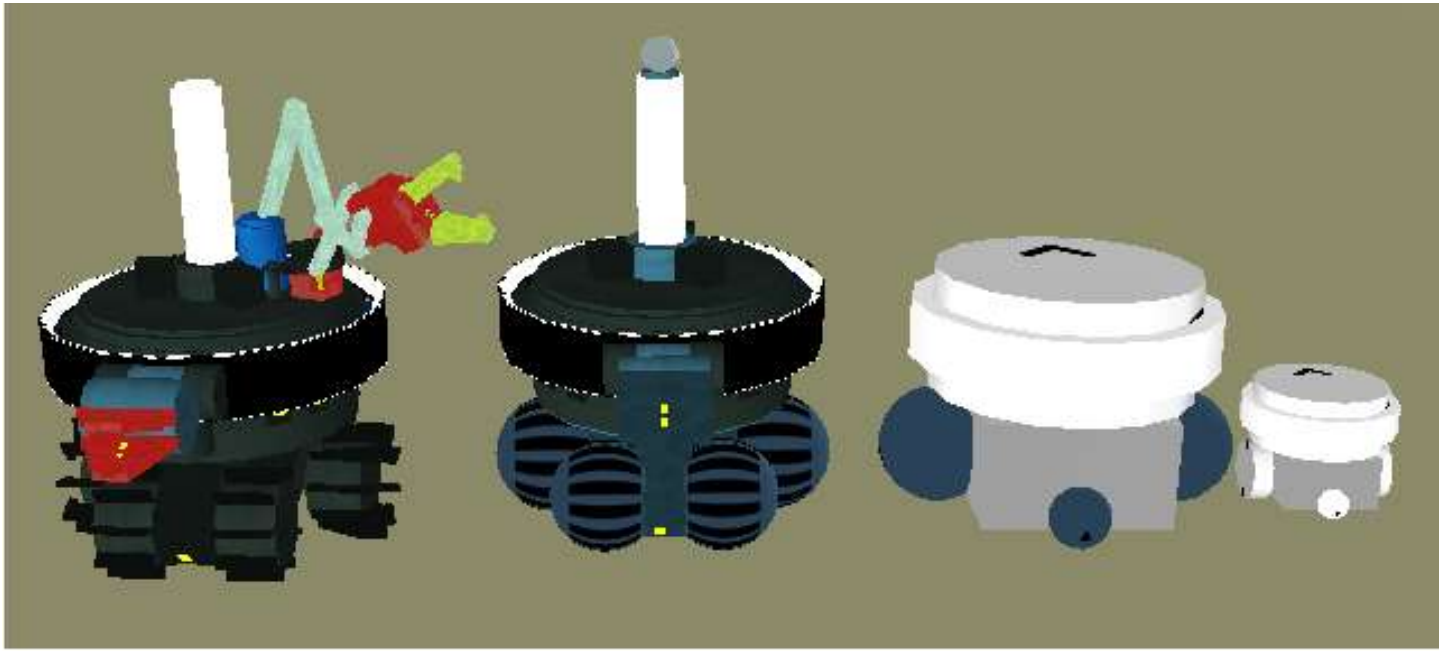
Simulation:
Different levels of detail



detailed medium simple fast

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Control Activities

- A **target scenario** has informed the research activities of the SWARM-BOT project
- Controllers have been designed for a variety of **individual** and **collective** behaviors
  - Aggregation
  - Coordinated motion
  - Cooperative transport (prey retrieval)
  - Path formation and exploration
  - Adaptive task allocation
  - Navigation on rough terrain
  - Functional self-assembling

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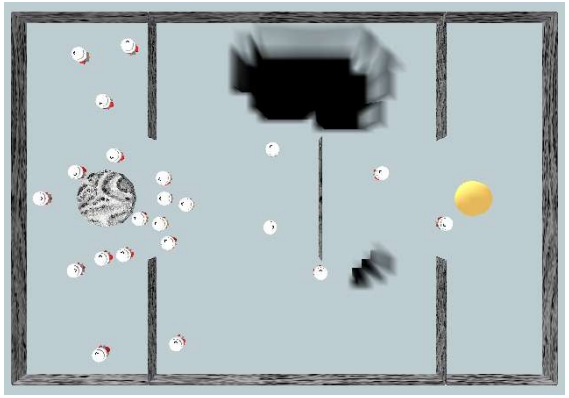
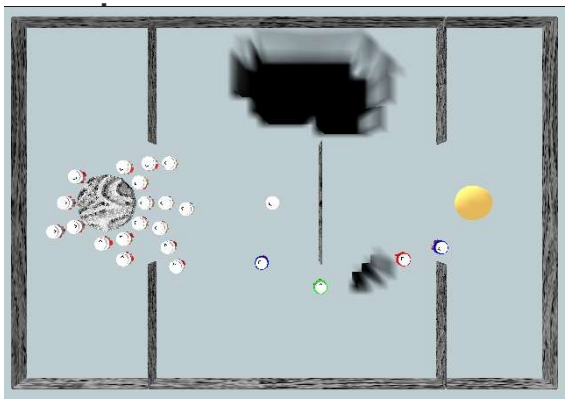
Control Activities:
The Project Scenario

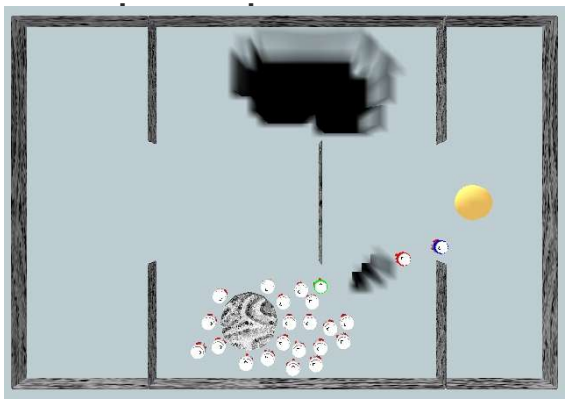
Find object and aggregate around it

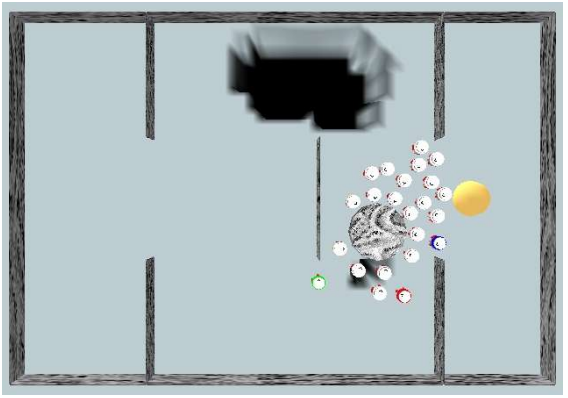


Pull object and search for



Change shape and move in a coordinate way avoiding





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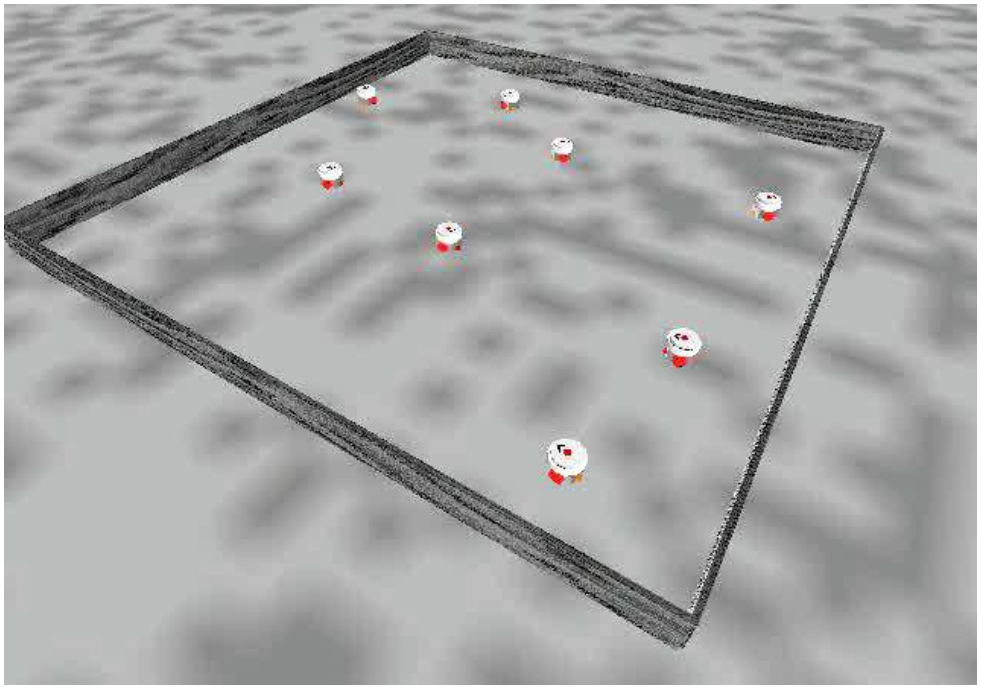
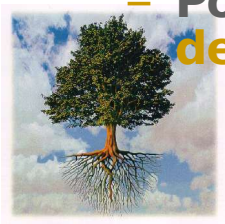
Control Activities:
Aggregation

- Aggregation is one of the basic abilities required by a *swarm-bot*
- *S-bots* are positioned in an arena bigger than their perceptual range
- *S-bots* use their sound signaling system to aggregate
- Artificial evolution of neural networks
  - Obtained simple and scalable behaviors (tried up to 40 *s-bots*)
  - Porting done on the detailed simulation model





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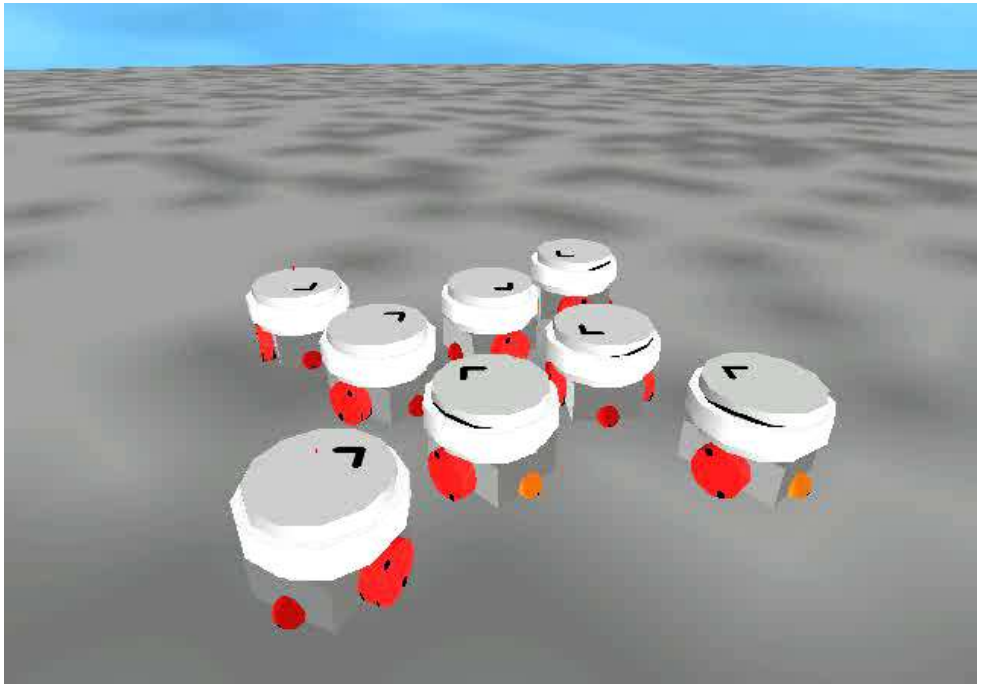
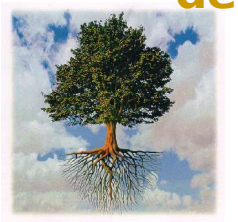
Control Activities:
Coordinated Motion

- Coordinated motion is another **basic ability** for a ***swarm-bot***
- Connected ***s-bot*** has to negotiate a **common direction** of motion
- Coordinated motion strategies exploits the **traction sensor**
- Artificial evolution of neural networks
  - Obtained **simple** and **scalable** behaviors (tried up to 40 ***s-bots***)
  - Porting done on the **detailed** simulation model





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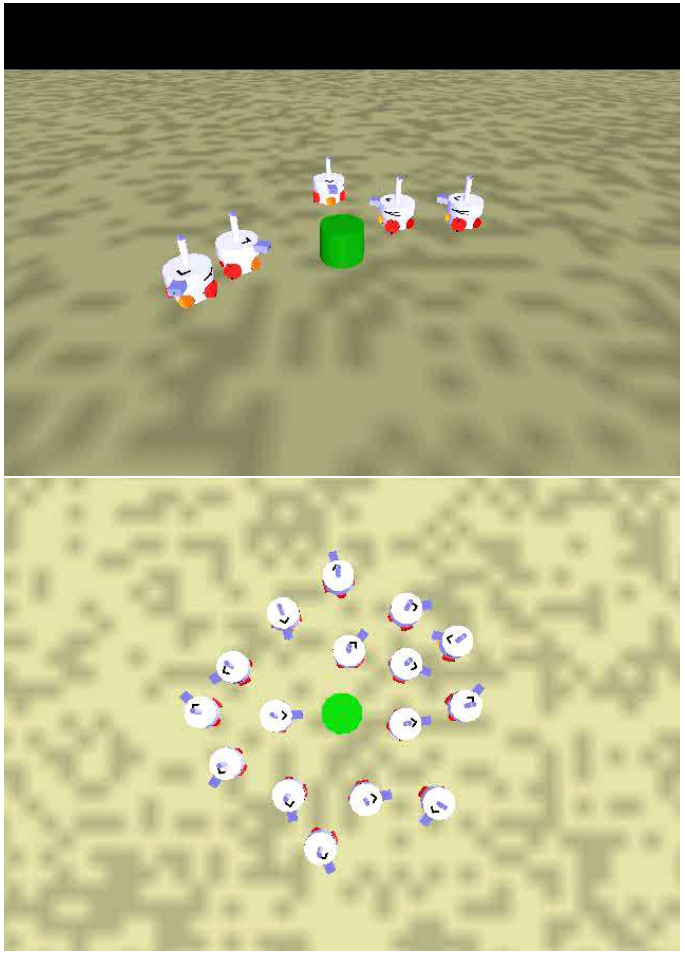
Control Activities:
Cooperative Transport

- Inspiration from ants behavior
- The goal is designing cooperative transport strategies for heavy loads
- *S-bots* may require to connect in a *swarm-bot* due to
  - The number of *s-bots*
  - The size and shape of the prey
- Behaviors evolved using artificial evolution
  - Normal and blind robots
  - Efficiency in the transport



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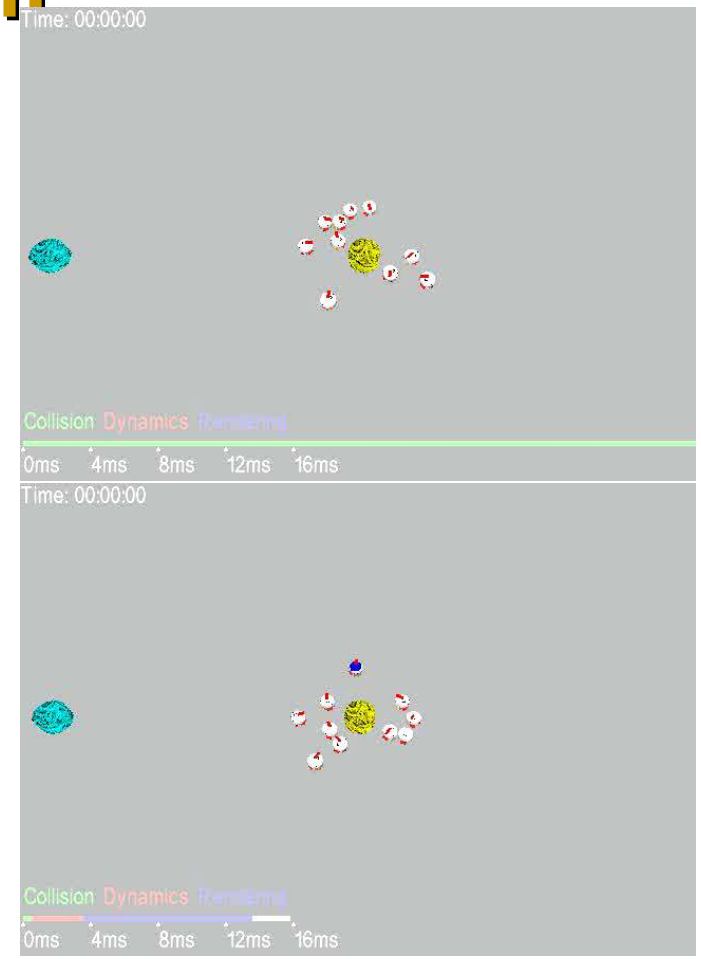
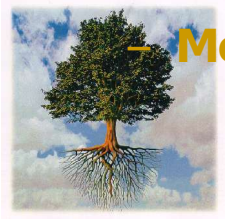
Control Activities:
Path Formation and Exploration

- Path formation is performed using *s-bots* as **colored beacons** that can be followed by others *s-bots* (**explorers**)
- Exploration by means of **chain formation**
  - starts from a **home location** (nest)
  - extends in **multiple directions**, eventually **connecting** to the goal
- Two main strategies designed
  - **Static** chain formation
  - **Moving** chain formation





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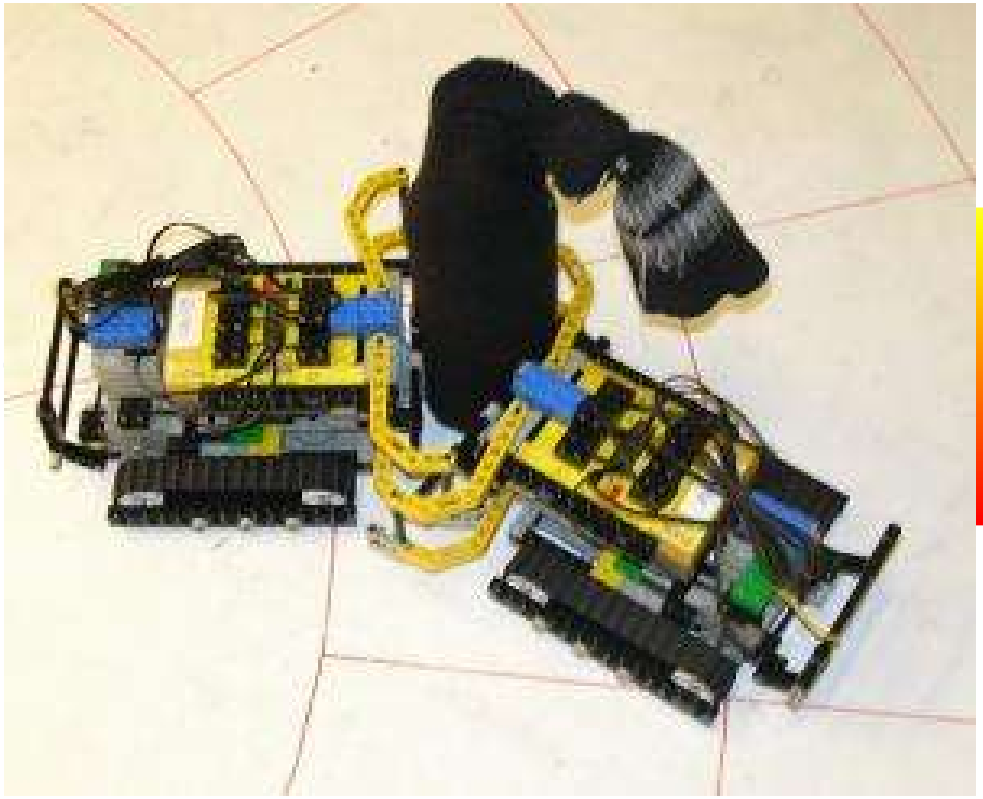
Control Activities:
Adaptive Task Allocation

- The aim is designing an **adaptive** task allocation mechanism that
  - Allocates a **sufficient number** of *s-bots* to a given task
  - Does not reduce the **efficiency** of the colony
- Task allocation has been studied in the context of **collective prey retrieval**
- The agents adjust the **probability** to leave the nest basing on previous **success/failures**
- This self-organizing process results in the choice of an **optimal number** of **active** agents



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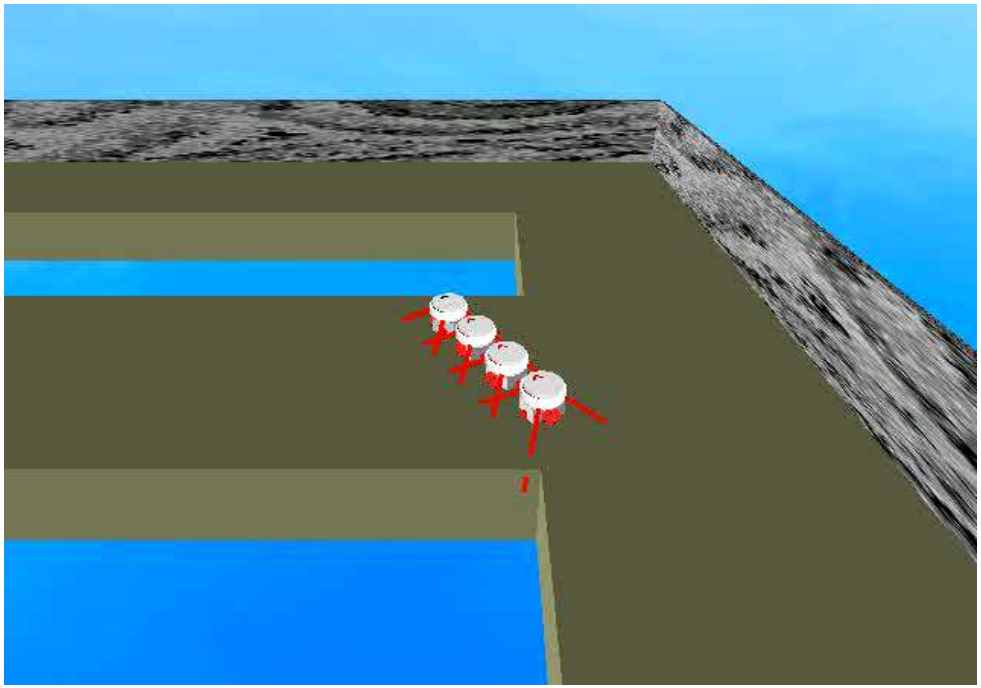
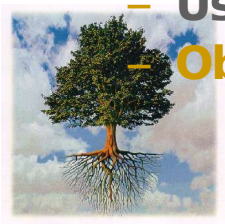
Control Activities:
All-Terrain Navigation

- All-terrain navigation is studied as the result of the **cooperation** of *s-bots* connected in a *swarm-bot* formation
- A first step is given by **hole avoidance**
  - *S-bots* have to move **coordinately** avoiding to **fall** into **holes** or out of the **arena borders**
- Evolved strategies generalize to
  - Different **size/shape** of the *swarm-bot*
  - Use of **flexible links**
  - **Obstacle** avoidance





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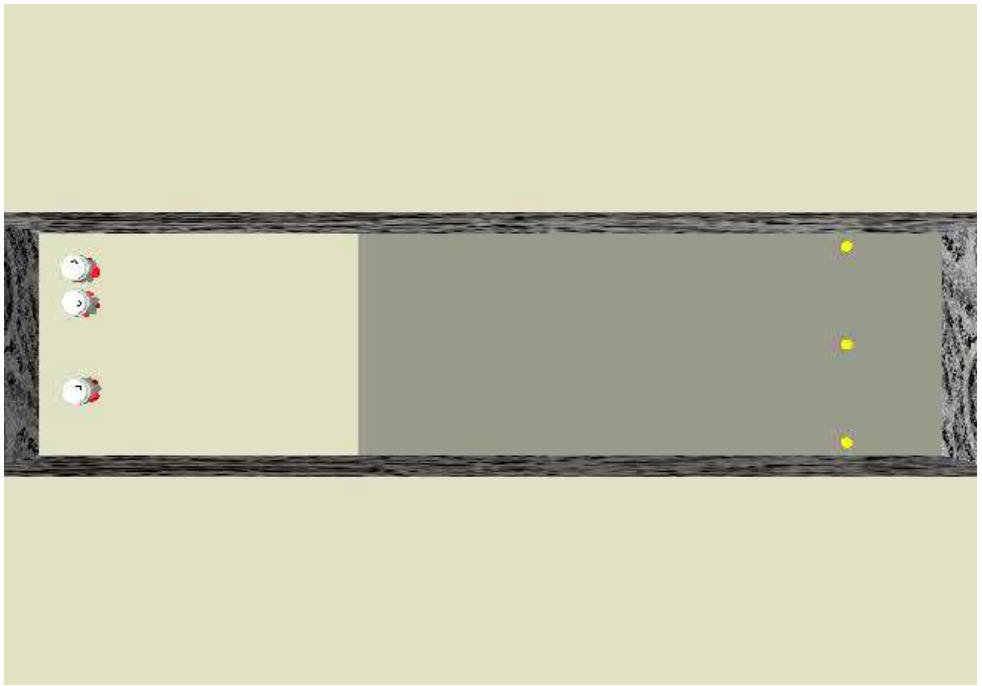
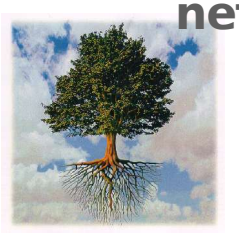
Control Activities:
Functional Self-Assembling

- Functional self-assembling is the **self-organized** creation of a **physically connected** structure which is **functional** to the accomplishment of a given task
- Studied in a **simplified** scenario, still rather complex
  - *S-bots* show a wide range of **individual** and **collective** behaviors
  - All behaviors are integrated in a **single**, **evolved** neural network





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Conclusions

- The SWARM-BOT project is bringing many innovations
  - **Advanced hardware** for self-assembling robots
  - **Interesting results** in the control activities
- Future Works
  - Implementation of the designed control strategy with the **real *s-bots***
  - **Integration** of different basic behavior for the solution of the **project scenario**
  - Study of **non-reactive behaviors** (integration over time, give up mechanisms, collective choices)

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Thank you

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SWARM-BOTS project partners

Control

ULB, B (M. Dorigo & J.-L. Deneubourg)

CNR, I (S. Nolfi & D.Parisi)

Simulation

IDSIA, CH (L. M. Gambardella)

Hardware

EPFL, CH (D. Floreano)

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