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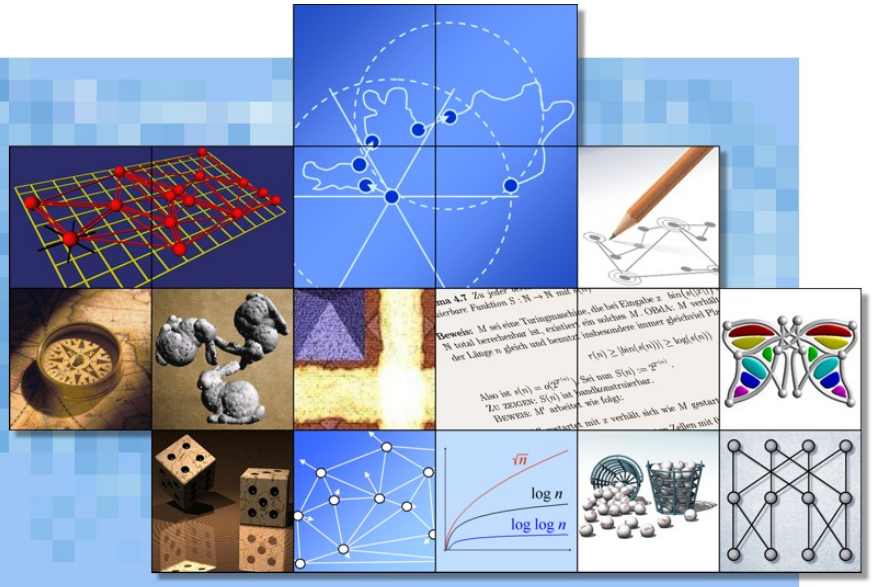
Smart Teams:
Local, Distributed Strategies for Self- Organizing Robotic Exploration Teams



Friedhelm Meyer auf der Heide

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The Smart Team

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Outline

- Goals of the “Smart Teams” project
- How does “Smart Teams” fit into Organic Computing?
- Realization of the project’s goals
- Current work

Main goal

- provide local and distributed strategies for collaborative exploration of unknown terrain
- heterogeneous robots exploring the terrain are organized as Smart Teams
- Goals of Smart Teams
  - Explore unknown terrains
  - Process “treasures” found in terrain,
    - respecting skills specific to particular robots
  - Guarantee connectivity
    - maintenance of communication networks for effective collaboration

Properties of developed strategies

- **distributed**
  - all decisions are made by the responsible robots, no central coordination
- **local**
  - decisions of robots are based on local, restricted information, without global knowledge
- **online**
  - robots do not know the future of the system
    - e.g. where treasures will be found
  - robots react to changes occurring online
- **dynamic environment**
  - changing environmental conditions, robots subject to faults

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- An approach to
  "Emergent behavior in technical systems"

- **Predictable emergence**
  - "Result-driven" approach
  - Local and distributed strategies are "simple rules"
  - Provable quality of global results from local behavior

- **Advantages**
  - Well-defined global result
  - Unwanted emergence impossible

Smart Teams and Organic Computing

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Smart Teams are self- organizing and adaptive

- **Cooperation**
  - local communication and emergent properties ensure that robots organize without help of a central authority
- **Developed strategies are online**
  - models for the development of strategies ensure that robots must react to changes appearing online
  - thus strategies are able to handle rapidly changing system state

Smart Teams are “self- healing”

- dynamical environment, including robot faults

Realization of goals

Three work packages

- Exploration of unknown terrains
- Processing of treasures
- Guaranteeing connectivity

Methods of analysis

- Competitive analysis for online strategies
- Worst-case analysis within practical models
- Empirical evaluation by simulation

Realization of goals
exploration of unknown terrain

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Goals for exploration of unknown terrain

- Smart Teams must organize themselves to jointly and efficiently explore an unknown terrain
- Exploration must be local, with no global communication

Problems

- Where is the greatest terrain complexity?
  - Maze: complicated, Desert: easy
- How to notify others that help is needed?

Approaches

- Inspiration from human strategies, usage of buoys, lighthouses and light vessels
- Adaptation to different forms of terrain
  - (searching a maze is different from searching a desert)

Realization of goals
guaranteeing connectivity

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Goals for guaranteeing connectivity

- Smart Teams may want to stay connected to communicate locally about exploration progress, tasks assignments ...
- Mobility of robots may break connections
- Only local, distributed strategies allowed

Approaches

- Employ robots as mobile relay stations which provide the communication backbone
- Limit the mobility of exploring robots

Realization of goals
guaranteeing connectivity

Further problems

- obstacles may disturb communication links in an unpredictable way
- faults of stations may break up communication paths

Realization of goals
processing treasures

Goals for processing of “treasures”

- Exploration leads to discovery of “treasures”
- Smart Team has to organize itself to schedule robots to perform processing of treasures
- Treasures may require robots with specific skills to process
- No hope for globally optimal solutions
  - we expect locally made decisions leading to good solutions

First results
guaranteeing connectivity

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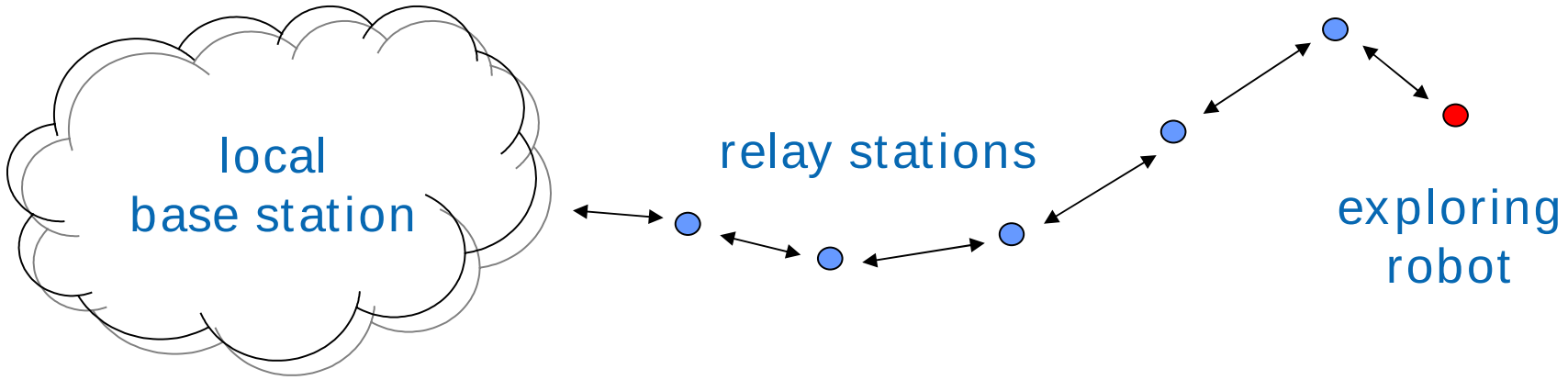
How to maintain a stable communication channel with small connecting path?

Model

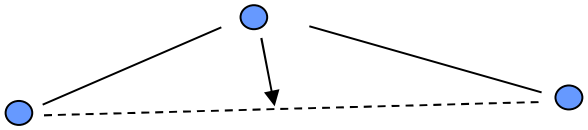
- Environment modeled as a plane with obstacles
- Local base stations for robots
- Exploring robots want to keep connected with base station
- Multi- hop communication because of small communication range
- Exploring robot moves in a (partially) unforeseeable way



First results
guaranteeing connectivity

Strategy for minimizing length of the connection path

- every robot keeps track of position of its immediate neighbors
- every robot tries to get to the middle of the segment between its neighbors



Results

- local, distributed strategy (only local communication necessary)
- adapts rapidly to changing position of exploring robot
- recovery from worst- case in at most $O(n^2 \log n)$ time

First results

guaranteeing connectivity

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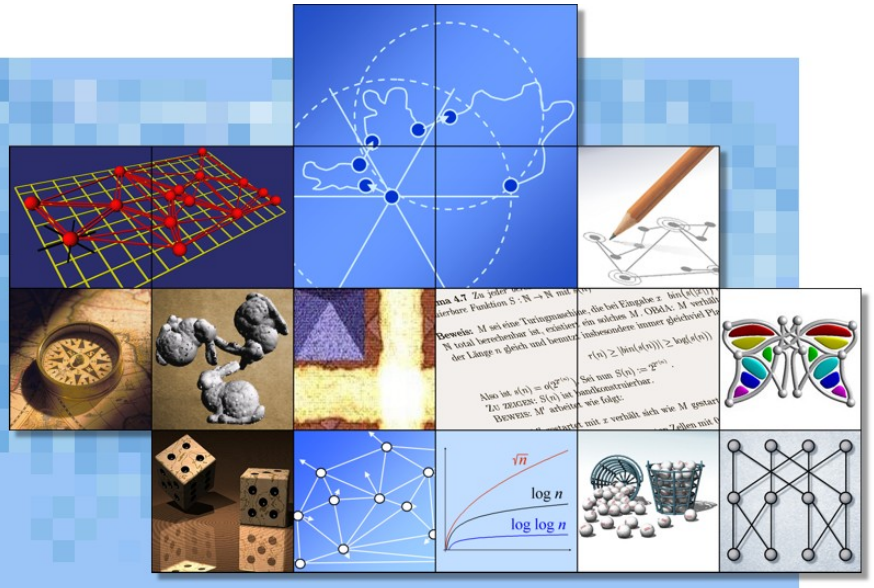
Illustration of strategy at work

Summary

Smart Teams realize

- Strategies for efficient discovery of terrain
- Strategies with organic behavior
  - Self-organization through local strategies
  - Adaptiveness to environmental changes by online strategies
  - Self-healing through fault tolerance of strategies

Thank you for your attention!



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