Smart Teams

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What is a Smart Team?

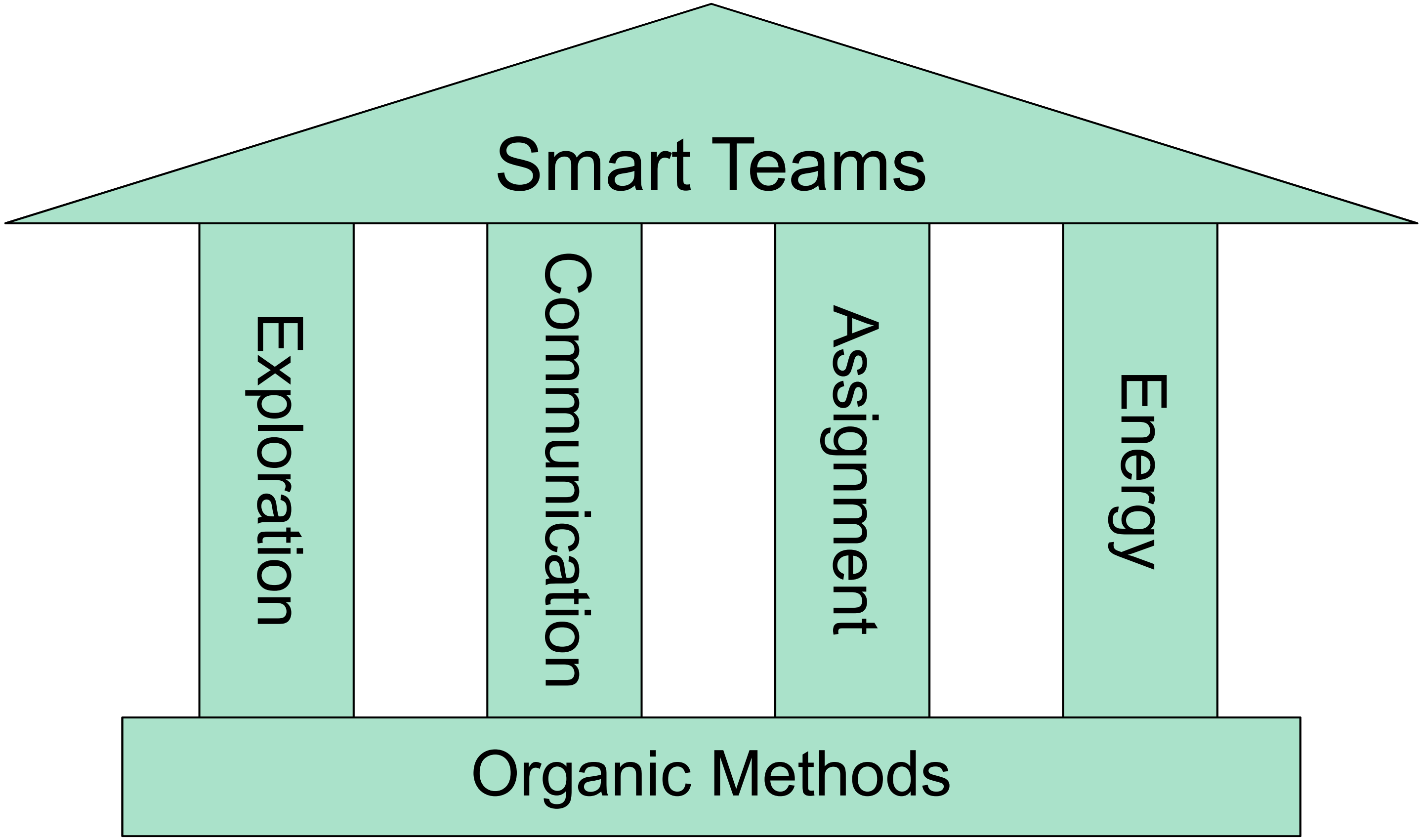
- A set of robots that is deployed in an unknown terrain
  - E.g. an outer planet or in an ocean
- No remote control: The robots have to organize themselves
- The robots are widely distributed in space
- Each robot can only contact few robots nearby

The Challenge

There is no global control guiding the Smart Team, so we need simple local rules for the robots that lead to globally good behavior

- Design of local algorithms
- Theoretical analysis: Worst-case analysis, competitive analysis of local distributed online algorithms
- Experimental analysis using simulators

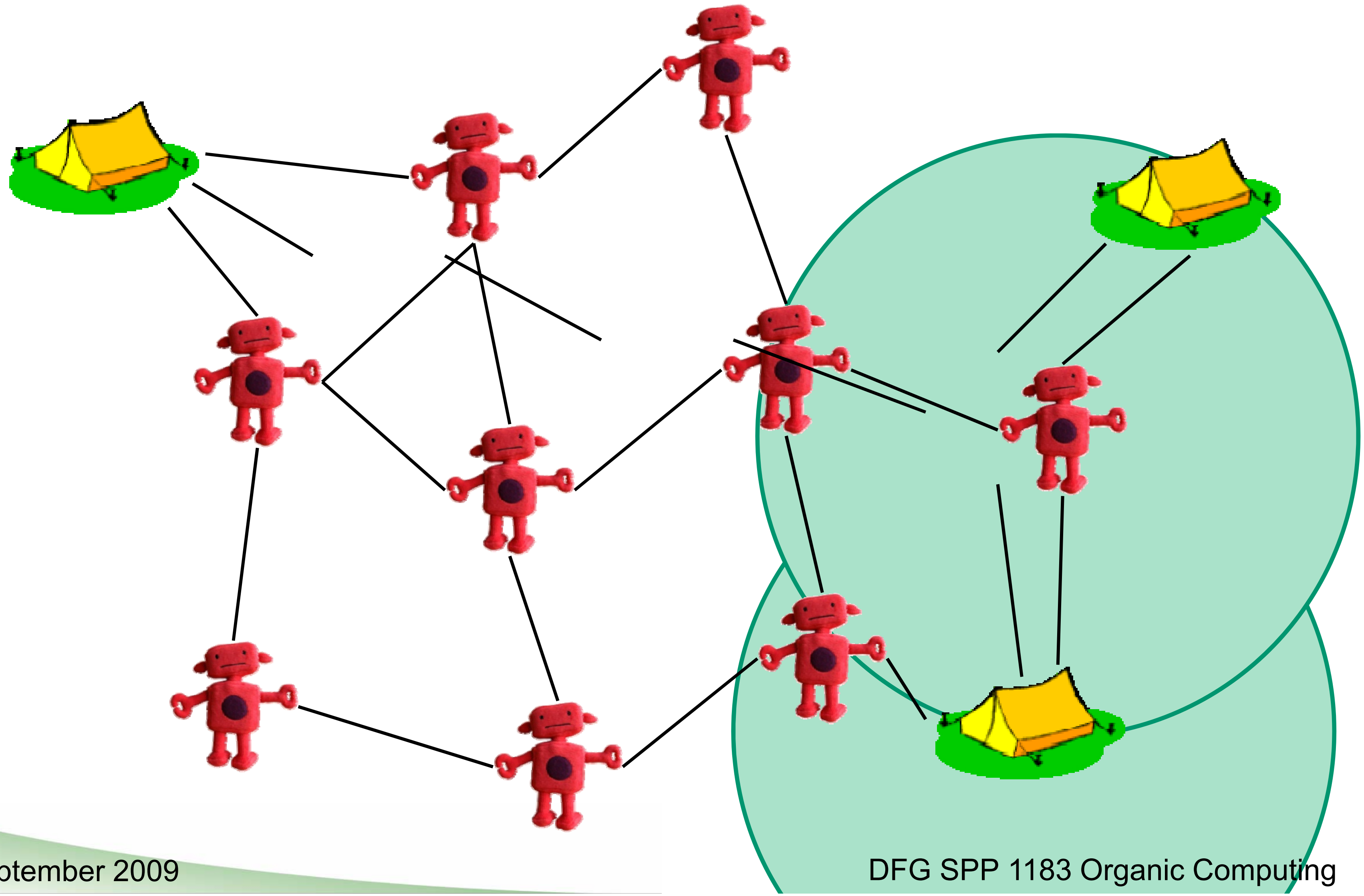
Smart Teams



Smart Teams
Exploration
Communication
Assignment
Energy
Organic Methods

Outline

- Introduction
- Subtasks
  - Communication
  - Assignment
- Conclusion



Communication: Overview

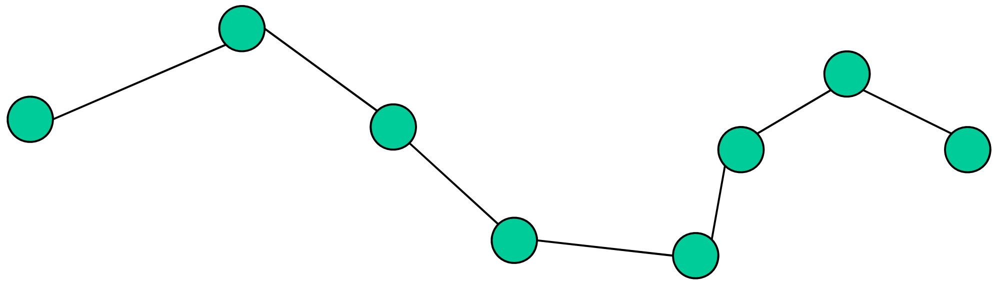
- Goal: Set up and maintain short communication infrastructure within the robot team
- Each robot has restricted communication range
  → Relay robots to forward communication
- Challenge: Relays have restricted capabilities and information
  - Viewing radius
  - Restricted communication
- Two models
  - Static
  - Dynamic

Communication

- Speed of convergence for Go-To-The-Center
- Gap between worst cases and experimental results
- Different time models:
  - Continuous: Relays move and watch/calculate continuously
    → no loss by propagation
  - Mixed: Relays can move a distance of ε in every round in the direction they compute
  - Cost measure: approximation factor for path lengths
- Strategies for dynamic setting with several mobile stations

2-Dimensional Case

- Maintaining communication structures
  - Mobile nodes have to maintain a communication infrastructure



  - Go-to-the-middle
  - Hopper-strategy

Results

- Different time models:
  - Continuous: Relays move and watch/calculate continuously
    → no loss by propagation
    - In the dynamic case: Optimal (up to constants) strategy
    - In the static case: $O(n)$ path length which is (up to constants) optimal in the worst case
  - Mixed: Relays can move a distance of ε in every round in the direction they compute
    - Preliminary results concerning number of hops and path length:
      - $\Theta(n^2+n/\varepsilon)$ steps
      - path length $\Theta(n^2\varepsilon+n)$

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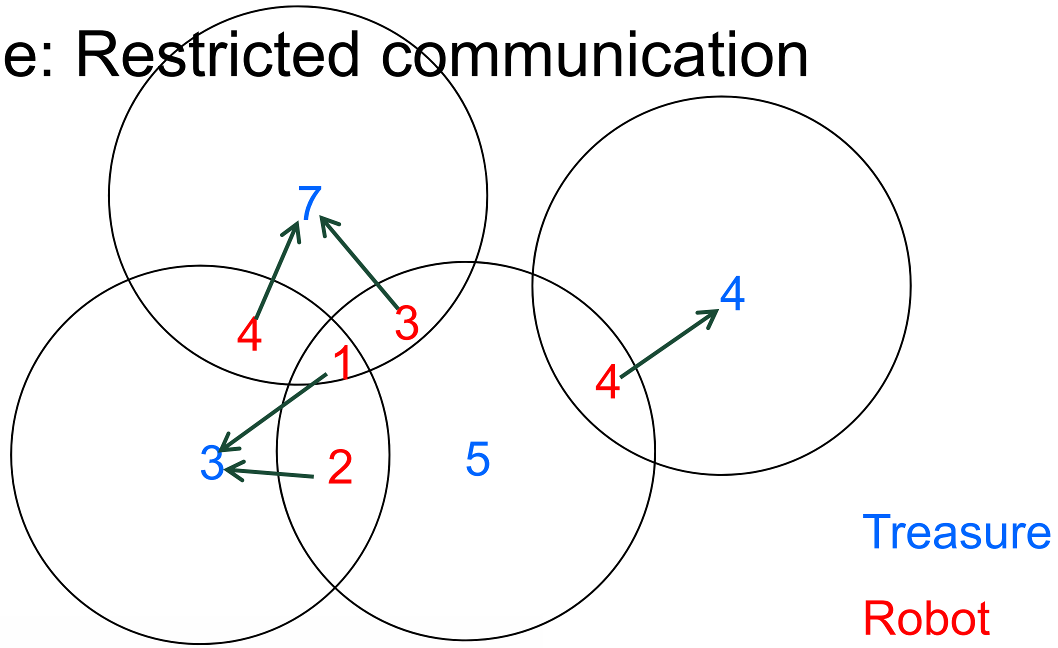
Assignment: Overview

- Robots have to fulfill tasks in the terrain
- Assign robots to tasks
- Form coalitions to fulfill the tasks
- Challenge: Restricted communication



Assignment: Results

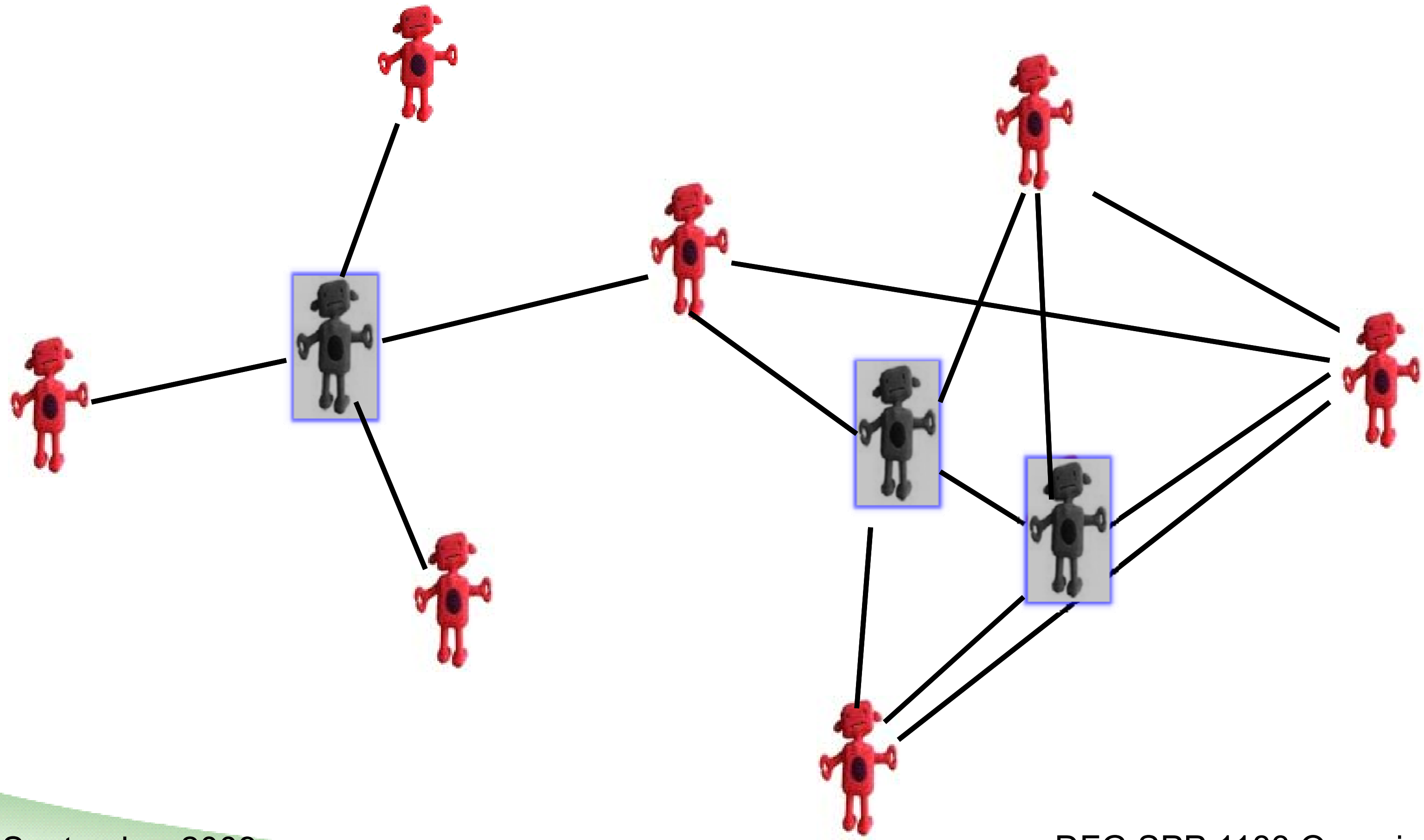
- Complexity of several scenarios
  - Only in few special cases solvable in polynomial time
  - NP-hard for most settings
- Local, distributed constant factor approximation algorithm for a general setting

Assignment: Outlook

- Local approximation algorithms without resource augmentation
- Different kinds of models
  - Relaxations on the locality constraints
  - Gravitational model

Assignment – tasks within the team

- Robots may serve different purposes
- They may switch their role depending on position and point of time
- E.g.: provide a costly service for other nodes



Model for the local case

- Each node keeps a simple invariant at its own location
- Each node informs all nodes in local neighborhood about
  - Current status (open or closed)
  - Current radius
  - Current weight (weighted number of points in vicinity)
- Communication performed by setting flags
- “Local neighborhood” means nodes in a geographic vicinity which is upper bounded by a constant

Analysis for the local case

- For a given (worst case) motion pattern analyze:
- The correctness (stabilizes in O(1)-approximation)? -Yes
- Time until stabilization? – O(log n) rounds
- Effect of motion
  - How large is the affected neighborhood? – Constant
  - How many robots are affected? – O(polylog) many
  - How often does a robot change its status? - Constant

Assignment: Outlook

- Robustness against temporary failures
  - Node failures
  - Mismeasurements
  - Sending wrong information
  - …

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Conclusion: Smart Teams in numbers

- 2 PhDs (Miroslaw Dynia, Jaroslaw Kutylowski)
- 19 papers
- 13 student theses
- 2 project groups (12 + 11 undergraduate students)
- …and continuing

Publications of Smart Teams

2009

- Bonorden, Olaf; Degener, Bastian; Kempkes Barbara; Pietrzyk, Peter: **Complexity and Approximation of Geometric Local Assignment Problem.** In: Proceedings of ALGOSENSORS, 2009
- Ooi, Chia Ching; Schindelhauer, Christian: **Minimal Energy Path Planning for Wireless Robots.** In: ACM/Springer Journal of Mobile Networks and Applications (MONET) 2009
- Degener, Bastian; Gehweiler, Joachim; Lammersen, Christiane: **Kinetic Facility Location.** In: Algorithmica, 2009
- Jaroslaw Kutylowski, Friedhelm Meyer auf der Heide: **Optimal Strategies for Maintaining a Chain of Relays between an Explorer and a Base Camp.** In: Journal of Theoretical Computer Science 2009.
- Ooi, Chia Ching; Schindelhauer, Christian: **Smart Ring: Utilizing Coverage Holes for Mobile Target Tracking**, accepted for publication in International ACM Conference on Management of Emergent Digital EcoSystems (MEDES'09), October, 2009.

Publications of Smart Teams

2008

- Degener, Bastian; Gehweiler, Joachim; Lammersen, Christiane: **The Kinetic Facility Location Problem.** In: Proceedings of the 11th Scandinavian Workshop on Algorithm Theory (SWAT), 2008
- Friedhelm Meyer auf der Heide, Barbara Schneider: **Local Strategies for Connecting Stations by Small Robotic Networks.** In: Proc. of 2nd IFIP International Conference on Biologically Inspired Computing (BICC'08)
- Chia Ching Ooi, Christian Schindelhauer: **Detours Save Energy in Mobile Wireless Networks.** In: Proc. of 10th IFIP International Conference on Mobile and Wireless Communications Networks (MWCN'08)
- Chia Ching Ooi, Christian Schindelhauer: **Energy-Efficient Distributed Target Tracking using Wireless Relay Robots.** In: 9th International Symposium on Distributed Autonomous Robotic Systems (DARS'08)

Publications of Smart Teams

2007

- Friedhelm Meyer auf der Heide, et. al.: **Smart Teams: Simulating Large Robotic Swarms in Vast Environments.** In: 4th International Symposium on Autonomous Minirobots for Research and Edutainment (AMiRE‘07)
- Chia Ching Ooi, Christian Schindelhauer: **Minimal Energy Path Planning for Wireless Robot.** In: Proc. of International Conference of Robot Communication and Coordination (ROBOCOMM’07)
- Miroslaw Dynia, Jakub Lopuszanski, Christian Schindelhauer : **Why Robots Need Maps.** In: Proc. of the 14th Colloquium on Structural Information and Communication Complexity (SIROCCO’07)
- Miroslaw Dynia, Miroslaw Korzeniowski, Jaroslaw Kutylowski: **Competitive Maintenance of Minimum Spanning Tree in Dynamic Graphs.** In: Proc. of the 33rd International Conference on Current Trends in Theory and Practice of Computer Science (SOFSEM'07)
- Marcin Bienkowski, Jaroslaw Kutylowski: **The k-Resource Problem on Uniform and on Uniformly Decomposable Metric Spaces.** In: Proc. of the 10th Workshop on Data Structures and Algorithms (WADS'07)
- Miroslaw Dynia, Jaroslaw Kutylowski, Friedhelm Meyer auf der Heide, Jonas Schrieb: **Local Strategies for Maintaining a Chain of Relay Stations between an Explorer and a Base Station.** In: Proc. of the 19th ACM Symposium on Parallelism in Algorithms and Architectures (SPAA'07)

Publications of Smart Teams

2006

- Miroslaw Dynia, Korzeniowski, Miroslaw, Christian Schindelhauer: **Power-Aware Collective Tree Exploration.** In: Proc. of the Architecture of Computing Systems (ARCS’06)
- Miroslaw Dynia, Andreas Kumlehn, Jaroslaw Kutylowski, Friedhelm Meyer auf der Heide, Christian Schindelhauer: **SmartS Simulator Design.**
- Miroslaw Dynia, Jaroslaw Kutylowski, Christian Schindelhauer, Friedhelm Meyer auf der Heide: **Smart Robot Teams Exploring Sparse Trees.** In: Proc. of the 31st International Symposium of Mathematical Foundations of Computer Science (MFCS’06)
- Miroslaw Dynia, Jaroslaw Kutylowski, Pawel Lorek, Friedhelm Meyer auf der Heide: **Maintaining Communication Between an Explorer and a Base Station.** In: IFIP 19th World Computer Congress, TC10: 1st IFIP International Conference on Biologically Inspired Computing (BICC’06)

Thank you for your attention!

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