

Report for PerAda website

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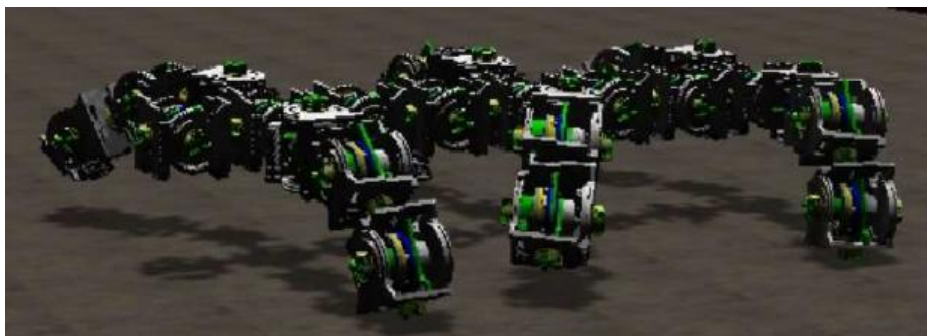
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The second international summer school with the topic “Screw-Theory Based Methods in Robotics” took place in Shanghai Jiao Tong University from 26/07/10 to 06/08/10. Seven experts in the robotic applications of screw theory were gathered together to teach attendees how to apply existing methods and empower them to develop new ones in their own research. In projects Symbion and Replicator the screw theory open a new methodology to deal with the high complexity of self-reconfigurable modular robots which are able to aggregate to artificial symbiotic organisms. The basic theoretical notions have been introduced in a rigorous manner, with emphasis on examples, applications, and exercises.

Projects Symbion and Replicator

In projects Symbion and Replicator, the core idea is to fulfill complex tasks such as rescue scenario using small mobile modular robots that are able to aggregate and build multi-robot organisms or operate together in a swarm mode.



The idea of developing artificial symbiotic organisms consist of modular aggregated robots was inspired by observing natural systems. Cells and organisms often live in colonies or swarms to achieve better survival capabilities. Even if they are not merged physically to one single organism they often share the same living space and their common resources. Since robots can only build organisms if they are connected physically to each other we need to combine engineering and scientific methods of

computer science to make such systems be able to act autonomously in a unpredicted environment.

The coordination, navigation or walking gait generation of locomotion with different topologies can be treated by bio-inspired approaches such as ANNs, hormone-based approaches, CPGs, etc. However, some problems are still better to handle with classical methods of robotics. Balancing, optimal or robust control design well known from the field of control theory is still required. However, there is a lack of methods that can apply to the reconfigurable robots with non-predefined topology. Classical modeling techniques for kinematics and dynamics need to be extended in order to make them adaptable to new topologies (structural adaptation). The complexity grows rapidly with the number of degrees of freedom (DOFs) such a robot organism can build. Achieving scalable and adaptive systems become a huge challenge.

Screw theory is one of the most promising approaches that give a possibility to handle this complexity. The main advantage of the screw theory is the fact that it is a geometrical approach and allows researchers to evaluate their results directly by using classical software tools such as Matlab or Maple and visualize the model in terms of vectors in a 3D space. The direct consequences of successful modeling of such systems lead often to big success in control and locomotion problems.

Seven Experts in Robotics

Dr. Roy Featherstone (The Australian National University)

6D formulation of the dynamics of individual rigid bodies and rigid-body systems. Equations of motion. Dynamics algorithms.

Dr. Jon Selig (London South Bank University)

Basic Lie group theory, matrix representations of the group of rigid-body displacements. Lie algebras as related to screw theory. The exponential map and its applications in modern robotics

Dr. Harvey Lipkin (Georgia Institute of Technology)

Mappings between screw spaces, stiffness and inertia. Structure of robot compliance. Eigenvalue problems and eigenscrews. Synthesis with springs.

Dr. Matteo Zoppi and Dr. Dimiter Zlatanov (University of Genova)

Velocity and singularity analysis of parallel and interconnected-chain mechanisms. Derivation of input-output velocity equations and singularity conditions.

Dr. Xianwen Kong (Heriot-Watt University, Edinburgh)

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Scalar products, dual spaces, reciprocity. Constraint and freedom in mechanisms. Constraint analysis. Type synthesis of single-loop mechanisms and parallel manipulators.

Dr. Feng Gao (Shanghai Jiao Tong University)

The GF set of basic motion units. Boolean calculation of the GF set. Type Synthesis of chain and parallel mechanisms.

Conclusion

Even if the bio-inspiration is the main focus of a project we should not neglect to combine classical approaches with bio-inspired since in general case there always exist advantages and disadvantages. Hybrid approaches have shown many times that they are much more powerful in comparison of using only either bio-inspired or only classical approaches. Since the most classical approaches are focused on fixed robot topologies additional theories are required to achieve adaptive behavior. Screw theory is one of the most promising approaches that give these opportunities.

Acknowledgment

We thank the PerAda funding program to provide the opportunity to benefit from seven experts in robotic who were gathered at Shanghai Jiao Tong University. Since the theory is still rarely taught at universities, it provides a big benefit and a good opportunity to learn how to apply these new concepts for problems of locomotion and control we face in the projects Symbion and Replicator.



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