Università di Genova

Robotics Group

Università di Bologna

GRAB

Fifth International Summer School on

Screw-Theory Based Methods in Robotics

3-11 September, 2014
University of Bologna, Bologna, Italy

www.summerscrews.org
summerscrews2014.ing.unibo.it

SUMMER SCREWS 2014

In 2014, our screw-theory school comes to the world's oldest university. In early September, Summer Screws'14 will gather six experts in the application of screw theory in robotics and up to 40 participants at the University of Bologna, Bologna, Italy. The school will teach attendees how to apply existing methods and empower them to develop new ones in their own research. The basic theoretical notions will be introduced in a rigorous manner, emphasizing examples, applications, and exercises. Scholarships are available.

Applications of the theory of screws are based on the combined representation of angular and linear velocity, or similarly force and moment, as a single element of a six-dimensional vector space.

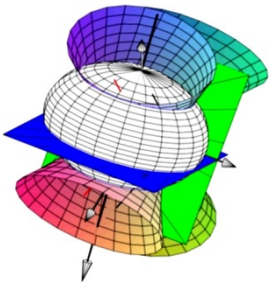
The importance of screw theory in robotics is widely recognised, in principle. In practice, almost nowhere is it taught to engineering students and few know how to use it. Yet, in a variety of areas of robotics, methods and formalisms based on the geometry and algebra of screws have shown to be superior to other techniques and have led to significant advances. These include the development of fast and efficient dynamics algorithms, discoveries in the nature of robot compliance and mechanism singularity, and the invention of numerous parallel mechanisms.

The instructors in the summer school are the authors of many of these results. They will teach the participants to apply existing techniques and to develop new ones in their own research. The key concepts will be introduced with mathematical rigour, but the emphasis will be on applications, with examples and exercises. This year's invited lecture by *Marco Carricato* is on *Persistent screw systems*.

The City and the University

Bologna, the capital of the Emilia Romagna region, is one of the most economically important cities in Northern Italy. It has the main rail and highway junction in the country, one of its most important trade fair grounds, and an increasingly busy international airport. The city offers a quality of life among the highest in Italy. The well–preserved historical city centre is one of the largest in Europe. The 40 kilometres of porticos (arcades), the red bricks of its buildings, and the medieval Due Torre are emblematic for Bologna.

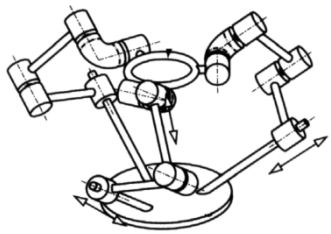
The University of Bologna, founded in 1088, is the oldest in the world and one of the best in Italy in current rankings. Dante, Petrarch, Pico della Mirandola, Leon Battista Alberti, Thomas Becket, Erasmus of Rotterdam, and Copernicus studied here. Luigi Galvani, discoverer of bioelectricity, Guglielmo Marconi, pioneer of radio, and Laura Bassi, the first woman in the world to hold a university chair, were UniBo scientists. Paracelso, Raimundo de Peñafort, Albrecht Dürer, Torquato Tasso, and Carlo Goldoni all spent time at the University.



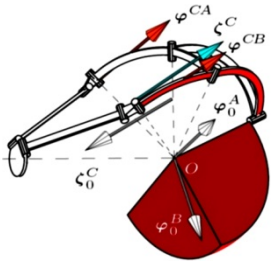
Basic vector-space properties of twists and wrenches: physical interpretation of the linear operations; linear dependence and independence, subspaces; bases and coordinates. (Lecturer: *Dimiter Zlatanov*)

Dimiter Zlatanov has used screw theory in the singularity and mobility analysis of mechanisms. He is the inventor of one of the first-known 4-dof parallel mechanisms and has presented courses and talks on screw-based methods in various universities.

Scalar products, dual spaces, reciprocity. Constraint and freedom in mechanisms. Constraint analysis. Type synthesis of single-loop mechanisms and parallel manipulators. (Lecturer: *Xianwen Kong*)



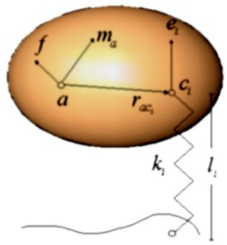
Xianwen Kong is the inventor of numerous parallel mechanisms and the co-author of the book Type Synthesis of Parallel Mechanisms. His results have been based on methods from screw-system theory.



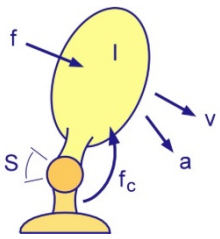
Velocity and singularity analysis of parallel and interconnected-chain mechanisms. Derivation of input-output velocity equations and singularity conditions. (Lecturers: *Matteo Zoppi* and *Dimiter Zlatanov*)

Matteo Zoppi has developed screw-theoretical techniques for the derivation and application of velocity equations for complex-chain manipulators. He is also the inventor of a number of mechanisms.

Mappings between screw spaces, stiffness and inertia. Structure of robot compliance. Eigenscrews. Synthesis with springs. (Lecturer: *Harvey Lipkin*)



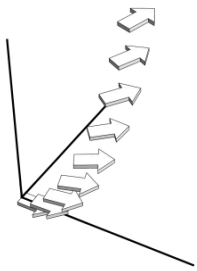
Harvey Lipkin has worked more than anyone on applying screw-theoretical methods in different areas of robotics and mechanisms, such as hybrid control, compliance, vibrations, and dynamics. He has taught various aspects of screw theory and supervised graduate students in the use of such methods.



6D formulation of the dynamics of individual rigid bodies and rigid-body systems. Equations of motion. Dynamics algorithms. (Lecturer: *Roy Featherstone*)

Roy Featherstone is the inventor of the Articulated-Body Dynamics Algorithm, and the author of the books Robot Dynamics Algorithms and Rigid Body Dynamics Algorithms. His ground-breaking work in dynamics has relied on a screw-theoretical formalism for the formulation of the equations of motion.

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. (Lecturer: *Jon Selig*)



Jon Selig is the foremost specialist on advanced geometrical and group-theoretical methods in robotics. He is the author of the book Geometric Fundamentals of Robotics, and several book chapters on the application of Clifford algebras and Lie group theory. He edited and co-authored the collection Geometrical Foundations of Robotics.

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