Knowledge Network of
Indian Institute of Technology, Gandhinagar
Under TEQIP-II Initiative (MHRD & Govt. of Gujarat)

Short Course on Geometry, Robotics & Control

Date: **12/12/2016 to 15/12/2016 (4 days)**
Time: 9:30 am reporting time on Dec 12
Venue: IIT Gandhinagar, Palaj Campus
Target group**:** Faculty, PG Students & Senior UG Students
Register At: www.iitgn.ac.in/kn
Registration closing date: 05th Dec, 2016

Venue, dates and time: IIT Gandhinagar, Palej (Dec. 12 - 15, 2016); 4 lectures each day, each of roughly 75 minutes duration.

Abstract: Conventional robotics addresses problems and tasks of mechani- cal manipulators - serial link manipulators, wheeled mobile robots, quadro- tors - operating on the ground or in the air. This field has grown from the 1960s and has reached a high level of maturity in terms of both mathematical and experimental development, and prototyping. The field has also spawned studies in the areas of geometric mechanics, nonholonomic systems, path planning and nonlinear control, and much of this development rests on tools from differential geometry. The objective of the workshop is to provide a foundation in differential geometry and examine the dynamics and control of robotics in this setting. The first two days will be largely devoted to developing the essential tools of differential geometry. The notion of rigid body motion and interconnected rigid bodies, that plays a major role in robotics, will then be presented in the geometric framework. Two popular models - the spherical mobile robot and the quadcoptor - will be modelled in a geomet- ric framework. Stabilizing control laws, preceded by a refresher in nonlinear control, will then be presented. Finally, the workshop will introduce the no- tion of locomotion in low Reynolds number, an area that is gaining much interest in the robotics community. Mobile cilia in paramecia, body shape changes in amoeba, beating flagella in bacteria like escheria coli are a few examples of mechanisms in the biological world locomoting in low Reynolds number. There has been a considerable activity spurred by the interest to develop mechanisms that use similar locomotion strategies at the micro and nano level - particularly in bioengineering and bio robotics.

Coordinator: Ravi N. Banavar, Professor, Systems and Control, IIT Bombay (on a semester assignment to IIT Gandhinagar).

Lecturers:

- Ravi N. Banavar, Professor, Systems and Control Engineering, IIT Bombay,
- Sudin Kadam, Karmvir Phogat and Aradhana Nayak, Senior doctoral students, Systems and Control Engineering, IIT Bombay.

Prerequisites: A good understanding of vector spaces or a course in linear algebra and linear control theory.

Who would benefit from this workshop? Graduate students, college teachers involved in robotics and control and wishing to understand geometric ideas in these fields.

Outline:

- **Day 1**: Refresher on vector spaces, an introduction to smooth man- ifolds, tangent vectors, tangent bundle and cotangent bundle. Intro- duction to Lie groups, Lie algebras and, in particular, the Lie groups SO(3) and SE(3), representing rotational rigid body motion and rigid body motion in 3-dimensional space, respectively.
- **Day 2**: A continuation of the machinery of Lie groups followed by Hamilton's principle, variational calculus on SO(3) and the rotational rigid body equations, interpretation of the Euler equations and appli- cations
- **Day 3**: Modelling of spherical mobile robots and quadcoptors in the geometric setting. A refresher of nonlinear control followed by stabiliz- ing control laws in the geometric framework
- **Day 4**: A continuation of feedback control laws followed by ideas of robotics and locomotion in fluids in low Reynolds number

References: **Main ones:**

Geometric Mechanics and Symmetry - D .D. Holm, T. Schmah and C. Stoica, Oxford University Press, 2009.

- *Nonholonomic Mechanics and Control* - A. M. Bloch, Springer, 2003
- *A Mathematical Introduction to Robot Manipulation and Control* - R. Murray, Z. Li and S. Sastry, CRC Press, 1992
- *Geometric Control of Mechanical Systems*- F. Bullo and A. D. Lewis, Springer 2005.
- *Introduction to Mechanics and Symmetry* - J. Marsden and T. Ratiu, Springer-Verlag, 1994.

Others:

- *An Introduction to Differentiable Manifolds and Riemannian Geometry* - W. M. Boothby, Academic Press, 1986.
- *An Introduction to Manifolds* - L. W. Tu, Springer 2008.
- *Ordinary Differential Equations* - V. I. Arnold, Springer, 92
- *Elementary Topics in Differential Geometry* - J. A. Thorpe, Springer 2004. *A Comprehensive Introduction to Differential Geometry* - M. Spivak, Publish or Perish Inc., 1979.
- *Control Theory from the Geometric Viewpoint* - A. Agrachev and Y. Sachkov, Springer, 2004.