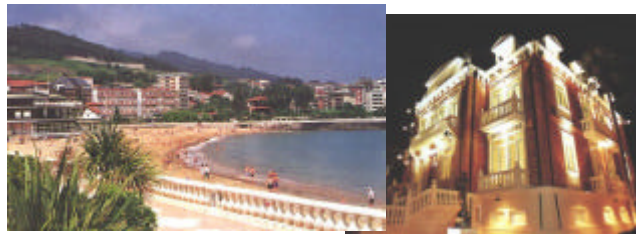


Distributed motion coordination of robotic networks

Jorge Cortés, University of California, Santa Cruz

Contents: Motion coordination is a remarkable phenomenon in biological systems and an extremely useful tool in man-made groups of vehicles, mobile sensors and embedded robotic systems. Just like animals do, groups of mobile autonomous agents need the ability to deploy over a given region, assume a specified pattern, rendezvous at a common point, or jointly move in a synchronized manner. Robotic teams and large-scale swarms are being considered for a broad class of applications, ranging from environmental monitoring, to search and rescue operations, and space imaging. Biology provides clear evidence that large-scale groups of animals coordinate their motion in order to efficiently pursue a collective objective. The collective behavior arises from local interactions, driven by individual goals, and with limited information exchange. The emergence of complex global behavior from simple local rules is by itself fascinating, and has generated a large body of literature in biology, physics, mathematics, and computer science. Modern technological advances make the deployment of large groups of autonomous mobile agents with on-board computing and communication capabilities increasingly feasible and attractive. As a consequence, the interest of the control community for motion coordination has increased rapidly in the last few years. This course will present analysis and design tools for distributed motion coordination algorithms. The introduction of the mathematical analysis techniques and design methodologies presented in the course will be done through application setups and examples from cooperative control, mobile sensor networks, and multi-agent robotic systems. The broad objective of the course is to illustrate ways in which systems and control theory helps us analyze emergent behaviors in animal groups and design autonomous and reliable robotic networks. The course will begin with an introduction to distributed motion coordination algorithms in biology and engineering (1 hour).

We will discuss some of the envisioned applications of robotic networks, and justify the need for modeling, analysis and design mathematical tools. Then, we will briefly discuss important notions from graph theory, distributed algorithms and linear iterations (1 hour). We will then be ready to model robotic networks and their interconnection topology, and introduce some complexity notions that characterize the execution of coordination algorithms (1 hour). The final lectures will be devoted to design and analyze cooperative strategies for different tasks, including rendezvous (1 hour), deployment (1 hour) and agreement (1 hour). In doing this, we will introduce beautiful mathematical tools that will help us analyze these problems.



Talk: Optimal Control of PDEs, Eduardo Casas (Univ. Cantabria)
This talk is an introduction to the Optimal Control Theory of Partial Differential Equations. We will formulate some different problems corresponding to distributed and boundary (Dirichlet and Neumann) controls of elliptic and parabolic equations. We will present the goals of the theory and the methods to achieve them will be exhibited through one example. Essentially we will consider the problem of the existence of a solution and its numerical approximation, providing error estimates for the discretization. The first and second order optimality conditions will be showed to be a key tool in the analysis of the control problem.

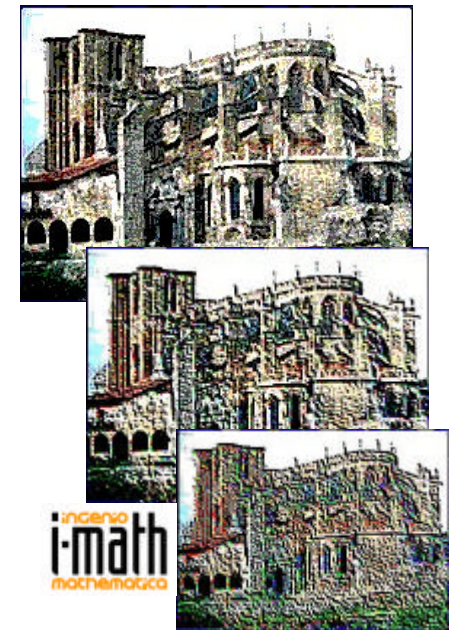
Scholarships

E-mail: gmcnet@ull.es

A limited number of scholarships for PhD students and advanced undergraduate students, that may cover Registration fees, lodging expenses or/and travel expenses, will be provided by the organizers. Applications, including a CV, should be sent before April 30, 2007 to gmcnet@ull.es

1st International Summer

School on Geometry, Mechanics and Control



Castro Urdiales
CIEM

June 25-29, 2007



3 ects credits

First International Summer School on Geometry, Mechanics and Control

The International Summer School on Geometry, Mechanics and Control is oriented to Ph.D. students and to post-doctoral students with undergraduate studies in Mathematics, Physics or Engineering, in particular to those who want to begin its research in geometrical aspects of mechanics, numerical integration, field theory and control theory. In this sense, the courses could be a complement to Ph.D. programs of different Universities. The School is also open to professionals who want to attend advanced and specialized courses oriented to geometrical techniques in those fields. It pretends to show an updated version of the knowledge of some basic problems in these topics and to present to the participants open problems and, in particular, the applications by means of specialized courses taught by the best international researchers in the respective fields.

The specific scientific profile of the School in 2007 is based on the research lines of Numerical Analysis (in particular, numerical integration), Geometric Mechanics and Control Theory with applications to Engineering, Robotics and Physics.



Minicourses

Geometric integration of Hamiltonian systems

J.M. Sanz-Serna, University of Valladolid

Contents: Numerical methods for the integration of ordinary differential equations have a long and distinguished history, but only flourished in connection with the digital computer fifty or sixty years ago. Typically those methods are universal in the sense that they may be applied to any differential system. While this feature has made it possible to build general-purpose software packages of wide applicability, it is clear that the one-size-fits-all approach cannot be optimal in all cases. It is therefore plausible to investigate whether special methods can be introduced to integrate restricted but significant special classes of differential systems. Often, the most salient feature of the special class under consideration is some geometric property of the solution flow and one attempts to design numerical methods that preserve that geometric property. This is the approach that originated in the eighties and now known as "Geometric integration". The most important example of geometric integration, both in terms of the range of applications (statistical simulations of gases and liquids, macromolecules, quantum chemistry, celestial mechanics, etc.) and of the volume of existing literature is the case of Hamiltonian systems. These are characterized geometrically by the symplecticness of their flows and one tries to design numerical integrators in such a way that the numerical solution also provides a symplectic transformation in phase space. The underlying hope is that symplectic integrators will better mimic the dynamic properties of Hamiltonian systems, particularly in long term integrations.

In the minicourse I will first review the history of numerical methods (one hour) and then present some background on Hamiltonian systems (one hour). After these preliminaries I will present the families of available symplectic integrators (three hours). The course will conclude by analyzing to what extent symplectic integrators outperform their classical counterparts.

Discrete Geometric Mechanics and Control

Melvin Leok, Purdue University

Contents: Geometric mechanics is concerned with the use of differential geometric and symmetry techniques in the study of Lagrangian and Hamiltonian mechanics. This approach serves as the theoretical underpinning of innovative control methodologies in geometric control theory that allow the attitude of satellites to be controlled using changes in its shape, as opposed to chemical propulsion. It is also the basis for understanding the ability of a falling cat to always land on its feet, even when released in an inverted orientation.

Such control algorithms rely critically on the geometric structure inherent in the mechanical system, and it is therefore natural to develop numerical implementations that are based on discrete analogues of Lagrangian and Hamiltonian mechanics, and discrete differential geometric techniques. This provides a systematic framework for constructing geometric structure-preserving integrators and geometric controllers for mechanical systems.

The minicourse will commence with a motivational overview of discrete geometry and mechanics, through the use of an illustrative example (one hour), followed by a discussion of the Lagrangian formulation of mechanics and its corresponding discretization (one hour). I will then show how exterior calculus is a generalization of vector calculus, introduce its discrete analogue, and discuss applications (two hours). Matrix Lie groups will be introduced, and applied to the construction of numerical schemes for rigid body dynamics (one hour), and the associated optimal control problem will be discussed (one hour).