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LECTURE NOTES IN CONTROL AND INFORMATION SCIENCES

366

Francesco Bullo
Kenji Fujimoto (Eds.)

Lagrangian and Hamiltonian Methods For Nonlinear Control 2006

Proceedings from the 3rd IFAC Workshop, Nagoya, Japan, July 2006

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Preface

This proceedings volume documents the 3rd IFAC Workshop on Lagrangian and Hamiltonian Methods in Nonlinear Control (LHMNLC'06) that was held in Nagoya, Japan, on July 19-21, 2006. The first workshop in this series was chaired and organized by Professors N. E. Leonard and R. Ortega, and was held in Princeton, USA, in March 2000. The second one was chaired and organized by Professors A. Astolfi, F. Gordillo and A. J. van der Schaft, and was held in Seville, Spain, in April 2003.

A vibrant synergy is documented between areas such as nonlinear control and optimal control theory, differential and Riemannian geometry, Lagrangian and Hamiltonian mechanics, nonsmooth optimization, and dynamical systems. The articles in this volume focus on technological areas including not only control of mechanical systems, but also geometric optimization, networked control, control of chemical processes, robotic locomotion, quantum systems, multi-agent systems, and robotic grasping and telemanipulation. Novel scientific contribution are proposed in a wide variety of techniques including synchronization, control Lyapunov functions, energy and power-based control, optimization algorithms, fault-tolerant control, geometric reduction theory, and iterative learning control, to name a few.

Financial support for the workshop was provided by the 21st Century COE Program (Tokyo Institute of Technology) "Innovation of Creative Engineering through the Development of Advanced Robotics," the Suzuki Foundation, the Daiko Foundation and the University of Nagoya. We also would like to thank all the participants to the workshop, all the members of the national and international organizing committees, the IFAC Secretariat, the IFAC Publications Committee, and the Springer-Verlag review board for the LNCIS series.

Santa Barbara, USA, and Nagoya, Japan,
June 2007

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Summary. This article challenges Bernstein's problem of redundant degrees of freedom (DOF) that remains unsolved from the control-theoretic point of view as well as from the standpoint of both neuro-physiology and robotics. Firstly, a rather simpler but mysterious control problem of movements of human-like multi-joint reaching with excess DOFs is analyzed from Newtonian mechanics and differential geometry. Secondly, another illustrative control problem that seems to be sophisticated and complicated is tackled, which is to find a sensory coordinated control signal for 3-Dimensional stable grasping and object manipulation by a pair of robot fingers with multiple joints under the effect of gravity and nonholonomic constraints. In each illustrative control problem, it is possible to find a simple control signal that renders each corresponding closed-loop dynamics stable on its corresponding equilibrium-point manifold. It is claimed, however, that convergences of solutions of closed-loop dynamics to an equilibrium-point manifold can not be analyzed by using Lyapunov's direct method, because a Lyapunov-like energy form can not be positive definite due to redundancy of DOFs. Instead, a novel definition called "stability on a manifold" based upon the concept of Riemannian distance on the constraint manifold is introduced in both illustrative problems and used in the analysis of convergence of solution trajectories. It is also shown that finiteness of Riemannian metrics plays an important role in evaluation of the performance of control in both problems.

1 Introduction

This paper is concerned with one of unsolved problems posed more than a half century ago by A.N. Bernstein as the Degrees-of-Freedom problem[14, 15], particularly, in case of human or robotic multi-joint movements of reaching as shown in Fig.1. The problem in case of Fig.1 is how to generate a joint motion so as to transfer the endpoint of an upper limb with four joints (shoulder, elbow, wrist, and finger MP joint) to a given target point $\boldsymbol{x}_d = (x_d, y_d)$ in the two-dimensional horizontal plane. Since the objective task $\boldsymbol{x}_d$ is given in the task space $\boldsymbol{x} \in X(= R^2)$ and the joint coordinates $q = (q_1, q_2, q_3, q_4)^{\mathrm{T}}$ are of four-dimension, there exists an infinite number of inverses q_d that realize $\boldsymbol{x}(q_d) = \boldsymbol{x}_d$

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