

Task-based Optimal Design of Robots

Workshop proposal for the 2014 IEEE International Conference on Robotics and Automation (ICRA 2014)

Cristiano Nattero
University of Genoa, Italy
cristiano.nattero@unige.it

Wei-Zhong Guo
Jiao Tong University, China
wzguo@sjtu.edu.cn

Fulvio Mastrogiovanni
University of Genoa, Italy
fulvio.mastrogiovanni@unige.it

Abstract—The *optimization* of the components of a robot system, with the aim of maximizing a given measure of performance, is required in most real-world robot tasks. Important early design choices are often taken according to the experience of designers rather than on formal methods, possibly causing a loss of optimality which cannot be easily recovered by successive optimization phases. On the contrary, efficient algorithms are available, which can handle large-scale and heterogeneous problems, possibly spanning different phases of a system design. The workshop aims at fostering the adoption of suitable optimization models and methods in early robot design phases. Such models are expected to outperform current state of the art approaches in designing advanced robot systems.

Index Terms— Robot design, task-based, optimization (and search) techniques, benchmarking.

I. PROPOSAL SUMMARY

Real-world robot tasks, to be executed in unstructured and highly dynamic environments, often require the *optimization* of some component of the whole robot architecture in order to maximize a given measure of performance (e.g., related to computational or energetic parameters). This is even more important when task-dependent functional requirements (e.g., related to safety or other operating conditions) must be guaranteed.

This Workshop aims at bridging two important, partly overlapping and constantly evolving fields of research, namely *optimal robot design* and *task-based design of robots*. The former features a wide adoption of optimization and search techniques in order to design robot parts, especially for what concerns their dimensioning, according to a number of optimality criteria. The latter, also known as *task-oriented* robot design, deals with a wider set of goals, including the choice between different kinds of mechanical designs and control architectures, the selection of the proper number of degrees of freedom as well as the kind of joints to be used, the adoption of a suitable locomotion system and part shape, just to name but a few.

Task-based design often precedes optimization. Although formal methods exist to determine the most appropriate type of mechanism for the task at hand, these are seldom applied to robot design and, in most cases, critical choices are based more on the *experience* of the designer and on empirical considerations rather than on a formal analysis of requirements and constraints. However, when considered as distinct design phases, we argue that a sequential approach cannot lead but to a suboptimal design.

From a survey of current literature it stems out that, on the one hand, task-based robot design seems to advocate for a wider adoption of optimization techniques, as witnessed by more than thirty years of successful application of optimization to robot design. Modern optimization models and methods, on the other hand, are ready to scale to a novel perspective in robot design, involving all of the objectives stated above.

The main objective of this Workshop is to foster the current debate in the application of optimization and search techniques to task-based robot design, in order to learn and spread good practices across the Robotics research community. The Workshop will try to address the following questions: What are the most relevant robot design problems to address in the upcoming few years? What are promising modelling methods to formalize such problems? Are there good practices to formalize a robot design problem as a well known optimisation problem? Are the existing performance measures suitable or is there a need for the introduction of new ones? Are there prototypical problems which robot design problems can be reduced to? Is it possible to identify benchmarking test cases? How to ensure and validate the consistency of the models from the early stages of the design process?

A. Format

Workshop, full day.

B. Main Organizer

Dr. Cristiano Nattero. Department of Informatics, Bioengineering, Robotics and Systems Engineering, University of Genoa, Via Opera Pia 13, 16145, Genoa, Italy. E-mail: cristiano.nattero@unige.it. Phone: +39 010 353 2801. Fax: +39 010 353 2154.

C. Co-organizers

Prof. Wei-Zhong Guo. Institute of Design and Control Engineering for Heavy Equipment, School of Mechanical Engineering, Shanghai Jiao Tong University, No.800 Dong Chuan Road, Shanghai, 200240, China. E-mail: wzguo@sjtu.edu.cn. Phone: +86 21 34206534.

Prof. Fulvio Mastrogiovanni. Department of Informatics, Bioengineering, Robotics and Systems Engineering, University of Genoa, Via Opera Pia 13, 16145, Genoa, Italy. E-mail: fulvio.mastrogiovanni@unige.it. Phone: +39 010 353 2324. Fax: +39 010 353 2154.

II. STATEMENT OF OBJECTIVES

The objective of the Workshop is to elicit and share best practices in order to (1) create a research community working on this topic (2) by means of well-defined case studies and benchmarking scenarios (3) in order to lead to a possible industry-oriented exploitation of results. We wish to: (i) introduce the use of optimization techniques from the initial phases of robot design, (ii) keep modelling overhead under control, (iii) shorten the time-to-market required to deploy real-world robot systems, (iv) identify categories of problems in task-based robot design, (v) assess key steps toward the development of new mathematical and software tools, (vi) identify and overcome common obstacles, as far as conceptual (e.g., unclear or undefined requirements), economical (e.g., a prototype is due in a short time) and cultural (e.g., knowledge gap between designers and mathematicians) aspects are concerned, (vii) identify novel ways of applying optimization techniques to task-based robot design, (viii) promote an industry-oriented exploitation of results.

Field experiences and success stories are particularly welcome.

III. INTENDED AUDIENCE

The Workshop is expected to be a forum for (both academic and industry background) researchers working in the design of robot systems. The Workshop will be characterized by a strong interactive and operative attitude. On the one hand, we will stimulate discussion by making all the contributions accessible to authors and participants (upon their agreement) beforehand. On the other hand, we will organize the event in order to maximize discussions and panel sessions over plain talks.

IV. PROGRAM COMMITTEE (PROVISIONAL)

Aude Billard (Ecole Polytechnique Federale de Lausanne, Switzerland), Stephane Caro (Ecole Centrale de Nantes, France), Howie Choset (Carnegie Mellon University, USA), Nak Young Chong (Japan Advanced Institute of Science and Technology, Japan), Feng Gao (Shanghai Jiao Tong University, China), Qiaode Jeffrey Ge (Stony Brook University, USA), Venkat N. Krovi (University at Buffalo, USA), Xinjun Liu (Tsinghua University, China), Katja Mombaur (Ruprecht-Karls-Universität Heidelberg, Germany), Francesco Nori (Istituto Italiano di Tecnologia, Italy), Emanuel Todorov (University of Washington, USA), Dan Zhang (Ontario Institute of Technology, Canada).

V. LIST OF SPEAKERS (PROVISIONAL)

Nikos Aspragathos (University of Patras, Greece), Tom Erez (University of Washington, USA), Serena Ivaldi (ISIR - Université Pierre et Marie Curie, France), Jin-Oh Kim (Kwangju University, Korea), James Kuffner (Carnegie Mellon University and Google, Inc.), Xinjun Liu (Tsinghua University, China), Vassilis Moulianitis (University of the Aegean, Greece), Alberto Rodriguez (Massachusetts Institute of Technology, USA), Panos S. Shiakolas (University of Texas at Arlington, USA), Wael Suleiman (University of Sherbrooke, Canada), Matteo Zoppi (University of Genoa, Italy).

VI. LIST OF TOPICS

The topics are related (but not limited) to: optimal robot design, task-based design of robots, optimization and search models and algorithms for robot design, benchmarking and use case scenarios, optimization-based design of robot mechanisms, software tools, market needs.

VII. RELATED WORKSHOPS/TUTORIALS IN PREVIOUS ICRA/IROS/CASES

During the past few years, a number of events have been organized, which are related to robot design, benchmarking and validation. Focusing on recent events only, the Tutorial on *Morphogenetic Robotics: A New Emerging Field of Self-Organizing Robotic Systems*¹ aims at introducing design principles based on evolutionary developmental Biology, systems Biology and biological morphogenesis. Electromechanical, computational and algorithmic aspects in robot design for planetary exploration are addressed in the Workshop *Planetary Rovers*². Actuation aspects (specifically related to hydraulics) for legged robots are the main topic of the Workshop *Design and Control of High-Performance Hydraulic Robots: Recent Advances and Perspectives*³. The Workshop *Evaluating effectiveness and acceptance of robots in surgery: user centered design and economic factors*⁴ is aimed at discussing how surgical robot design impacts on their acceptance in everyday and market-oriented situations. Design issues (with a specific emphasis on industrial standardization and benchmarking) are considered in the Workshop *Human Robot Interaction for Assistance and Industrial Robots. Scientific Knowledge, Standards and Regulatory Frameworks. How do I design for the real world?*⁵.

Although all the previous events take design issues into account, there is no actual focus on formal, optimization-based methods and procedures for task-based robot design.

Finally, it is noteworthy that some of the aspects we aim at discussing are also part of the activities carried out in the context of the IEEE-RAS Technical Committee on *Model-based Optimization for Robotics*⁶.

VIII. PAPER REQUIREMENTS

Researchers presenting their results at the Workshop will be requested to submit a 4-page extended abstract, including figures, tables and references. We will ask the contributors to dedicate a specific (mandatory) section of the abstract to suggest answers to the questions posed in the Proposal Summary and (optionally) to introduce new ones. The extended abstracts will form the Workshop Proceedings. We are evaluating a post-Workshop extended publication of results, either as an edited book or a journal special issue.

¹<http://www.ece.stevens-tech.edu/~ymeng/ICRA11-Tutorial.htm>

²<http://ewh.ieee.org/conf/icra/2013/workshops/PlanetaryRovers/>

³<http://www.iit.it/advr-events/icra-2013-ws-on-hydraulic-robots.html>

⁴<http://www.eurosurge.eu/eurosurge/events/workshop-icra-2013/>

⁵http://www.kontor46.eu/kontor46/ICRA_2013_Workshop.html

⁶<http://orb.iwr.uni-heidelberg.de/tcopt/>