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A DSL for adaptive robot kinematics

A RISE worldwide project in software engineering for smart and adaptive robotics systems

1 Project outline

This is a two-month project in the area of software engineering for robotics applications.

1.1 Background

A key problem in robotics is that robots need to become more adaptive to changing environment conditions. This is particularly important where robots are to interact with humans, a key direction of current research. However, current robotics research already faces problems of adaptation for much simpler cases. For example, bipedal robots are currently unable to walk from asphalt onto sand without stability issues; human walkers achieve this while chatting to their friends. More adaptation requirements invariably make the software controlling the robots more complex.

One solution to this problem of increasing software complexity might come from developing dedicated programming languages that allow developers to focus on different key aspects of the overall problem independently. For example, a language might enable the expression of robot control programs without the need to consider in detail the robot physics. In software engineering, the development of such dedicated higher-level languages (often called domain-specific languages or DSLs) has been intensively studied over the past two decades or so. However, the application of these ideas to robotics, and in particular to the area of adaptive robots, is still relatively unexplored.

1.2 Aims and Objectives

This internship project aims to develop a DSL for specifying the basic physical structure of robots as well as rules for adapting this structure (*e.g.*, by stiffening a joint) in reaction to environmental and internal triggers. The outcome of the project should be the definition of the DSL together with a supporting tool environment for writing and testing programs written in the DSL. DSL programs should produce a set of kinematics equations describing the behaviour of the physical structures described as well as a simulation program for analysing the modelled behaviour through visual inspection. This should be validated on a case study (e.g., using the rimless-wheel setup available at King's and previously described in [1, 2]).

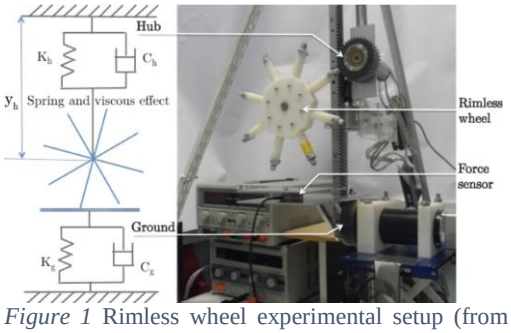

Figure 1 Rimless wheel experimental setup (from [1])

A basic prototype of some aspects of the language (but crucially not the adaptive aspects) to be developed has already been produced and can be found on Github.[1] The outputs of this RISE internship should extend and feed into the prototype available on Github.

To achieve the above aims, the project has the following objectives:

[1] https://github.com/szschaler/RigidBodies

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1. Obtain a working knowledge of DSLs and DSL development;
2. Perform a domain analysis of the domain of kinematics for adaptive robotics;
3. Develop suitable extensions to the current DSL and its tool environment;
4. Evaluate the work done through a number of case studies; and
5. Publish the outcomes of the internship to at least conference level.

1.3 Work plan

The internship is planned to last for 8 weeks and will proceed approximately as outlined below:

Week	Tasks
1	*Familiarisation.* During this week, the intern will learn about domain-specific languages and their development as well as about the basics of adaptive robotics and kinematics. This will be achieved through a broad literature study as well as introductory sessions with the supervisor and academics/PhD students from a robotics background. In addition, the student will develop simple tutorial-style DSLs and explore the prototype of the basic language that already exists.
2	*Initial domain analysis.* Depending on the background and progress of the intern, part of this week may still be used for familiarisation. However, the majority of the time will be focused on discussion with the robotics PhD student and the development of initial pen-and-paper concepts of new language concepts to support adaptive robotics.
3 – 6	*Incremental development of language prototype.* The main part of the internship will be spent iteratively developing and refining the existing language prototype in collaboration with the robotics PhD student to produce and iteratively evaluate a language version that supports adaptive robots. Each increment will be validated against the case study providing input for further refinement of the prototype.
7/8	*Reporting.* The final two weeks will primarily focus on reporting the outcomes of the internship, including, but not limited to, the production of a paper draft to be submitted to a suitable international research conference.

Of course, as with any research project, the work plan will need to be adjusted based on initial findings. However, the incremental and iterative nature of the majority of the work will help us mitigate any potential issues we will come across and achieve a high-quality outcome in any case. All work will be regularly supervised by Dr Zschaler. The intern will further have regular interaction with experts in robotics both at the academic and the PhD-student level.

2 Knowledge and skills to be acquired by the intern

This project provides a unique opportunity for the intern to acquire in-depth experience of research in software engineering at a world-leading university.
Academically, this will strengthen the intern's software development skills, in particular in object-oriented programming, language design and implementation, and domain analysis. Moreover, the RISE internship provides an opportunity to learn more about the area of adaptive robot kinematics and its underlying challenges with a hands-on approach based on existing real-world prototypes.

At the same time, the internship will help strengthen the interns set of soft skills, including his/her English-language knowledge, ability to develop and express a consistent argument, skills in critical analysis of existing research literature, stakeholder interaction and requirements analysis, and time management skills. All of these skills will be of great use to the intern regardless of whether he/she will subsequently consider an academic or industrial career.

3 About the host institution and city

King's College London is the fourth-oldest university in the United Kingdom and is the most central of the London universities. King's is among the top 20 universities worldwide according to the latest QS World University Rankings. King's is a member of the Russel Group of research-intensive UK universities and is well known for its strong research capability.

The Department of Informatics is situated on the Strand campus of King's, right next to Somerset House and in walking distance of Covent Garden, Trafalgar Square, Houses of Parliament, and the West End. The UK Research Excellence Framework (REF) 2014, a process of expert review to assess the quality of research in UK higher education institutions, ranks the Department 8th in the country according to the 'power' metric, which takes into account both the quality and quantity of research activity. The Department's activities span all aspects of computer science and robotics, including work in software engineering, soft robotics, machine learning, agent-based software, bio-informatics, and planning.

Dr Zschaler is a senior lecturer in the Department of Informatics. His research is in software engineering, in particular in the areas of model-driven engineering (including the development and use of domain-specific languages), component-based engineering, and software quality properties.

Little needs to be said about London. London is one of the top tourist attractions worldwide, but also boasts an impressive amount of industry primarily driven by finance and technology. London's technology start-up scene is now at a par with that of Silicon Valley, and many major tech companies have substantial offices (including, in some cases, their headquarters) in London.

King's has strong support for international students, including excellent support with accommodation issues. We are looking for interns who are European citizens. These interns would not require a visa for their time in the UK.

4 References

[1] V. Pereno, K. Shoar, G. Bartoli, F. Bianchi, and Th. Nanayakkara. *Stable Walking on Variable Visco-Elastic Terrains using Meta-parameters for Passive State Migration.* Proc. IEEE/RSJ Int'l Conference Intelligent Robots and Systems (IROS'13), 2013.

[2] F. Bianchi, G. Bartoli, K. Shoar, M. R. Armas Fernandez, V. Pereno, J. Zirjakova, A. Jiang, and Th. Nanayakkara. Adaptive Internal Impedance Control for Stable Walking on Uncertain Visco-elastic Terrains. Proc. IEEE/RSJ Int'l Conference Intelligent Robots and Systems (IROS'12), 2012.