



UTS

UNIVERSITY
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SYDNEY

Code for Success Software Development for Robotics Competitions

by **Sammy Pfeiffer**

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and
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AUTHOR'S DECLARATION

I, *Sammy Pfeiffer* declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the *School of Software, Faculty of Engineering & Information Technology* at the University of Technology Sydney. This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis. In addition, I certify that all information sources and literature used are indicated in the thesis. This document has not been submitted for qualifications at any other academic institution. This research is supported by the Australian Government Research Training Program.

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ABSTRACT

Robotics technologies have the potential to change the way we live for the better by reducing the difficulty of, helping with, or completely automating tasks. Robotics competitions such as RoboCup aim to push the field forward while providing an environment for participants to acquire important skills and knowledge. Most participants in these competitions are university teams with members from different backgrounds and levels of expertise, using different types of robots. These diverse teams must develop large and complex software stacks to accomplish their respective competitions' objectives.

This thesis aims to improve the software development process for these teams in regards to the development experience and competition outcomes. This will help push forward the robotics field and, consequently, our quality of life.

The available literature about software development methodologies for non-professional teams in robotics competitions is currently limited. The objectives of this thesis include enlarging the available knowledge in this domain and creating a practical set of guidelines that improve the software development experience and outcomes for robotics competitions. In order to do this, the software development methodology of the *UTS Unleashed!* team was analyzed over three consecutive years of participation in the RoboCup@Home Social Standard Platform League from the point of view of the development lead. Additionally, expert feedback was gathered to analyze, discuss, and compare the software development methodology of other teams and experts in the RoboCup League.

The research methodologies used in this thesis are Action Research, to explore *UTS Unleashed!*'s case study, and Grounded Theory, to analyze expert feedback gathered from a workshop and survey of members of the RoboCup community.

To the author's knowledge, this thesis presents the first longitudinal case study on a competitive team participating over multiple years in a robotics competition. Moreover, with the team under study achieving victory in their third year of participation. Furthermore, it is the first work showcasing expert feedback on a RoboCup teams' software development process from the RoboCup community.

This thesis concludes with a set of guidelines for software development practices for teams participating in robotic competitions. These guidelines offer insights and advice to improve competition team software development experiences and outcomes.

DEDICATION

To myself and my mental health. I never thought I would ever get this far.

To all the people that have supported me in one way or another up to getting here. At this point, I sweetly remember the teachers in Sa Colomina who pushed me to go to university and helped me get my first scholarship.

To all the people that believed in me, especially when I did not know any better.

To my friends who have always shown me that they are my family. I cannot express this in the same way in English, so here it is in Spanish:

Aunque la lista de nombres de todos los que me habéis inspirado y habéis estado ahí en los buenos y malos momentos, antes y durante este doctorado, es probablemente demasiado larga, he de dar las gracias a algunos de vosotros directamente y dedicaros esta tesis doctoral.

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I acknowledge Jonathan Vitale and Meg Tonkin for their support and sportsmanship. Without you in the lab, I doubt I would have gotten this far.

I acknowledge Neil McLaren for his help during the RoboCup preparation and competition and his dedication in proofreading my thesis.

Finally, I acknowledge every member of The Magic Lab that was part of this journey. At different points in time each one of you did or said something or just were there when it was most needed.

PERSONAL MOTIVATION

Understanding my story with regards to robotics competitions helps frame the context of this work. Here I will describe it in first person.

I have been taking part in robotic competitions and challenges since my early university days in Spain in 2007. I attended a robotics course where we built a sumo fighting two-wheeled robot, which also could do line following, and at the end of it, there was a competition between the participants.

I joined the robotics club¹ that offered the course. The club organized the largest robot sumo fighting competition nationally, I became part of the organization and helped members develop platforms to participate. I participated with other team members in competitions such as the *Lunabotics NASA robot design competition* and a variety of local hackathons in Barcelona.

In 2012 the robotics company PAL Robotics came to our club to look for talented students interested in robotics to create a team to participate in RoboCup@Home with one of their new robots *REEM*, a real-size humanoid robot as can be seen in Figure 1.

¹The club was called AEES Estudiantes, from Aerospace & Electronics Systems Society Students, and welcomed anyone with interest in robotics and new technologies.



Figure 1: The robot REEM at RoboCup@Home in Eindhoven in 2013. I'm on the left with another former member of the club, Jonathan Gonzalez. Great times.

I joined the project, and it changed my life. We did not make it for the 2012 edition of RoboCup@Home, but we tried again in 2013. We successfully qualified and participated. We put tremendous effort in, the team was talented and motivated (Figure 2), but it was not enough. The bar was set extremely high, and we did not manage to focus on the correct directions to maximize the output of our efforts.



Figure 2: The 2013 team for RoboCup@Home, called REEM@IRI.

Thanks to this project, I joined PAL Robotics as an intern and afterward as an employee. I got motivated to get robots to **actually** become a reality, and to be part of a team that effectively, and in an enjoyable journey, enables robots to work in the real world.

In the following years, I have participated in RoboCup@Rescue, NASA Space Robotics Challenge, Move-it/Moving self-driving car hackathons, among others. I have learned and performed better individually but also as a team. My results have been positive, achieving podiums and awards in these competitions.

There is something victorious teams do that makes them successful. In this work, I want to take the unique opportunity to use the participation in Robocup@Home Social Standard Platform League (SSPL) over three consecutive years to uncover insights and strategies that help teams achieve exceptional outcomes.

LIST OF PUBLICATIONS

1. PFEIFFER S., EBRAHIMIAN D., HERSE S., LE T. N., LEONG S., LU B., POWELL K., RAZA S. A., SANG T., SAWANT I., TONKIN M., VINAVILES C., VU T. D., YANG Q., BILLINGSLEY R., CLARK J., JOHNSTON B., MADHISSETTY S., MCLAREN N., PEPPAS P., VITALE J., WILLIAMS M.A. (2019, July). *UTS Unleashed! RoboCup@Home SSPL Champions 2019*. In Robot World Cup (pp. 603-615). Springer, Cham.
2. MAGYAR B., TSIOGKAS N., DERAY J., PFEIFFER S., LANE D. (2019). *Timed-Elastic Bands for Manipulation Motion Planning*. In IEEE Robotics and Automation Letters, 4(4) (pp. 3513-3520).
3. TONKIN M., VITALE J., OJHA S., CLARK J., PFEIFFER S., JUDGE W., WANG X., WILLIAMS M.A. (2017, November). *Embodiment, privacy and social robots: May I remember you?*. In International Conference on Social Robotics (pp. 506-515). Springer, Cham.

IMPACT

This thesis presents further contributions to society alongside the scientific publications directly related to it. Namely:

- Under the development of this thesis the *UTS Unleashed!* RoboCup@Home SSPL team achieved second place and best Human Robot Interface award in 2017 in Nagoya, Japan, second place in 2018 in Montreal, Canada, and won in 2019 in Sydney, Australia (the team's hometown).
- The outcomes of the *UTS Unleashed!* team were communicated in the media multiple times ².
- The software stack developed for the RoboCup@Home SSPL participation powered social robotics experiments in hospitality and hospital scenarios³.
- Parts of the software stack⁴ were made open source for the benefit of the robotics community and beyond. Other parts of the system will be open sourced in the near future.
- The rulebook for the RoboCup@Home competition was improved as part of this work.

²For example, in Gizmodo: <https://www.gizmodo.com.au/2017/07/meet-australias-newest-robocup-team/>, IoTHub: <https://www.iothub.com.au/news/uts-researchers-to-develop-ai-for-robot-waiter-466625>, InsideRobotics: <https://www.insiderobotics.com.au/robotics/personal-robots/Pepper-scores-a-world-class-goal-for-Sydney-team-in-RoboCup/>, UTS media: <https://www.uts.edu.au/about/faculty-engineering-and-information-technology/news/uts-brings-home-gold-home-robocup2019>.

³The publications related to this work are pending at the time of writing this thesis.

⁴Pepper robot simulation: https://github.com/awesomebytes/pepper_virtual, Continuous Integration for the Gentoo Prefix Operating System: https://github.com/awesomebytes/gentoo_prefix_ci, pre-compiled Robotics Operating System (ROS) for unsupported platforms: https://github.com/awesomebytes/ros_overlay_on_gentoo_prefix, pre-compiled Operating System, libraries and applications for the Pepper robot to participate in RoboCup@Home SSPL: https://github.com/awesomebytes/pepper_os.

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- Improvements in the popular open source robotics framework ROS were submitted during the work of this thesis.
 - This work presents the first detailed description and evolution of the software development methodology and technical approaches of a competitive team for the RoboCup@Home SSPL competition during three consecutive years.
 - This work presents a set of guidelines to help new and existing teams to improve their experience and outcomes when participating in robotics competitions.

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