# UTS Unleashed! 2019 RoboCup@Home Social SPL

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**Abstract.** UTS Unleashed! were the only Australian team that qualified for 2017 and 2018 RoboCup@Home Social SPL. It won the Human-Robot Interface Award in 2017 and took second place in the competition in both 2017 and 2018. UTS Unleashed! has a strong track record of contribution at RoboCup since its first competition in 2003: the team developed the first dodge and dribble behaviours in the SPL Soccer league, and won the Scientific Challenges in the SPL Soccer league in 2004, and were runners up in 2004 and 2008[1]. The key focus of the UTS social robotics team is human-robot interaction, knowledge representation, cognitive architectures, emotional and social intelligence, decision making behaviour, software engineering, legal and ethical implications of social robots. Our work is foundational and pragmatic. We aim to develop breakthrough theory and translate into innovative practical methods, and feed our results back into theory development.

## 1 Introduction

The Innovation and Enterprise Research Lab (Magic Lab[2]) at UTS is Australia's leader in Social Robotics and has Australia's only PR2 robot. We work with government and industry partners to develop socially intelligent robots[3]. We investigate and develop tools to make robots socially acceptable, highly engaging and able to efficiently co-operate with humans in the home, work place and public environments [1–3].

Our interest in competing at RoboCup@Home Social SPL is to use the focus and effort required to develop a competitive Human-Robot Interaction (HRI)

[1] More details of our track record can be found on our Team Website `http://utsunleashed.webnode.com`
[2] The Magic Lab at UTS `http://themagiclab.org`
[3] CBA Robot Chip takes a trip to the airport `http://www.computerworld.com.au\ \/article/626400/cba-robot-chip-takes-trip-airport`

system that will help to build momentum and intensity towards scientific advances in socially-aware service-robotics. As a team of software-oriented roboticists we see significant value in the opportunity to use a Standard Platform like Pepper together with Open Source software to leverage and enrich the work of others in the RoboCup community. It provides a unique opportunity for our team to contribute to a major international scientific effort that has tremendous knowledge sharing and scaling benefits.

As Australia's leading social robotics group we are well positioned to disseminate scientific advances back into 'real word' applications [4–6]. We have been in a significant research partnership with Australia's largest bank leading to several research outcomes [7–11]. During this research partnership we collaborated with Australian major commercial businesses. This includes research studies in collaboration with the largest diversified property group having interests in large shopping centres and retirement villages [12], and one of the world's leading commercial airlines [13]. Currently, our research agenda is strategically considering the design, development and testing of robotics applications in public spaces in Australia by collaborating with government bodies and public hospitals. All these motivated research partners help us apply our research to real-world situations. This affords an extraordinary opportunity to test ideas, insights and prototypes in situations beyond our research laboratory and the RoboCup@Home test environment [12, 13, 7, 9, 11]. For this reason, RoboCup@Home Social SPL is an outstanding test-bed for our social robot applications, potentially leading to high impact research outcomes for the international robotics community.

## 2 Background and Main Research Contributions

The main research focus of our team is the development of easy to use, highly extensible and intuitive tools shaping social robot autonomous and intelligent behaviour for human-robot interaction, collaboration and engagement. Particular focus is given to shape social intelligence in robots [14], so as to allow them to safely co-exist and interact with people in human-centred environments [15, 1]. Hence, we aim to provide theoretical and practical outcomes that can be used by the robotics research community to efficiently orchestrate the capabilities of the robot platform (vision, speech recognition, human-robot interaction, display of emotions) drawing inspiration from cognitive and biological studies.

Our research lab has a strong track record of contributions in social robotics field. Specifically, we focus on the following key areas:

1. Human-Robot Engagement [1, 12];
2. Software Architecture for Continuous Integration;
3. Web technologies for Human-Robot Interaction;
4. Design of social robotics commercial applications and Human-Robot Interaction experimentation [6, 12, 7, 9, 13, 8, 10, 11];
5. Models of emotion[16–18]
6. Legal and ethical implications of social robots[4, 8]

7. Policy and governance of social robots in society[4]

### 2.1 Human-Robot Engagement

Our vision consists in ensuring Pepper builds trust and enhances human well-being.

We employ a human-centric methodology that champions social intelligence [14] and human rights [19] with a strong focus on enhancing accessibility and human experience. We use our extensive HRI experiment outcomes [11, 17, 9, 12, 8, 1] to inform our robot behaviour designs.

Our HRI designs respect the rights of human users. For example, we ensure they are in control of how their information is collected, shared, and stored by the robot. Privacy is a basic human right and of critical importance in social robotics. This frames our research focus. We work directly with the United Nations on developing ways that ensure social robots demonstrate social intelligence [20] and respect Human rights [21, 19].

Human-Robot visual communication via our novel tablet animations increase accessibility by augmenting other modes of human-robot interaction such as sounds, speech, gesture and eye lights. They are generated from a bespoke JavaScript engine and comply with strong UTS branding guidelines[5].

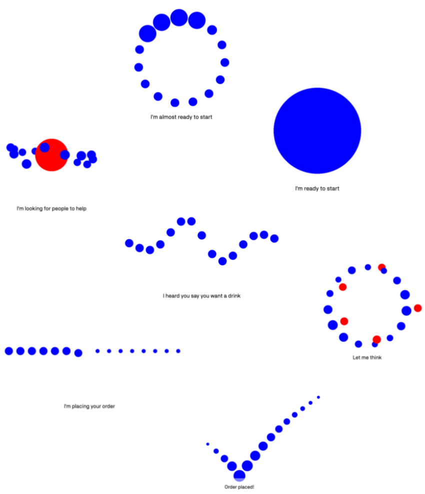


**Fig. 1.** Tablet animations.

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[4] Designing Effective Policies for Safety-Critical AI `http://bitsandatoms.co/effective-policies-for-safety-critical-ai/`

[5] `http://newsroom.uts.edu.au/news/2017/05/we-are-uts`

### 2.2 Software Architecture for Continuous Integration

We divide our software into named packages, and store each package in a separate `git` repository. When new code is uploaded to the central server[6], it triggers a "continuous integration" (CI) pipeline for that project. The specific tasks in that pipeline vary from one project to the next, and are defined by a file in the repository and configuration variables on the server. Those tasks are run within containers[7] on an in-house computer controlled by a daemon[8].

A typical CI pipeline consists of **build**, **test**, and **publish** stages, where each stage runs only when the previous one completes successfully. When all stages pass, the published package is uploaded to our in-house package repository. This is an special case of the "Strictly separate build and run stages" principle from "The Twelve-Factor App" [22].

The resulting package repository gives us confidence that when we install version X of a package, we are getting the code that went through the **publish** stage when its version was marked as X. Which in turn went through the **test** stage for that same commit, which has the results of those tests stored in the CI history. Ideally, we can add unit tests to the package to detect regressions in functionality and prevent new versions from being published with previously-encountered errors. When we are unable to detect regressions with testing (common for packages that depend on stateful hardware such as robots), a developer who encounters a regression can replace version X with a previous version so that their productivity is not blocked by temporary errors.

### 2.3 Web Technologies for Human-Robot Interaction

We created a Web-based application named *Magic Tablet* for facilitating Human-Robot Interaction.

*Magic Tablet* consists of a JavaScript frontend that runs on Pepper's chest tablet, and a Python backend that controls the frontend by sending messages through the NAOqi messaging API.

The frontend displays textual status messages at the top and bottom of the tablet screen, and an animation or image in the middle of the screen. These are typically used by interaction designers to confirm what the robot has heard, what it has said, and to characterize its state as "listening", "processing", "navigating" or so on.

We have found that abstract animations to communicate the robot's state are more appropriate than animated facial expressions, as they are displayed on the robot's chest and not its head.

We have also found that persistently displaying what the robot has just said is very helpful in noisy environments such as the RoboCup arena.

[6] GitLab (`https://gitlab.com/`) central source control server
[7] Docker (`https://www.docker.com/`) containers
[8] the **Gitlab Runner** daemon (`https://docs.gitlab.com/runner/`)

### 2.4 Design of Social Robotics Commercial Applications and Human-Robot Interaction Experimentation

Our lab is actively involved in the design of robotics commercial applications to situate in public spaces and interacting with humans. For the design of these applications we use a design methodology unifying 2 practices for designing the User Experience (UX) of HRI. i) **Lean UX** [23] and ii) **Agile Science**[9] [24].

We successfully used this methodology to create a UX design process for HRI that both assists in creating a viable application and an enhanced user experience in several domains, such as banks, shopping centres and airports [7, 12, 9]. In addition, our suggested UX design process have been used to easily design experiments to test psychological and sociological effects of HRI for the considered applications.

In this perspective, RoboCup@Home is a significant opportunity to showcase our robotics commercial applications, to gather feedback from robotics community and to test the HRI of the designed systems.

## 3 New Social Robotics Cognitive Architecture for 2019

A new agile next-generation cognitive architecture, BUNJI, is being developed for RoboCup 2019 based on the insights gathered during our experience at RoboCup 2017 & 2018, see Fig. 2. BUNJI means friend in several Australian Aboriginal languages.

In order to allow a range of high-level reasoning approaches a common modular low level layer is needed. We call this layer, *Skills* (saying a sentence, for example). Composing one or more skills creates a *Capability* (e.g., answering a question).

These *Skills* and *Capabilities* can be orchestrated to create plans to achieve tasks, from subtasks such as a RoboCup test (which itself can become a *Capability*) to a full competition test.

*Capabilities* are internally represented as SMACH State Machines[25] so we can take advantage of their properties and pre-existing tools.

In order to move away from the simple state machine based approach, which plagues the league we make use of a whiteboard of common knowledge called *Beliefs* which our reasoning engine uses in conjunction with the *Capabilities* of the robot to dynamically create plans to solve the RoboCup tests as if they were General Purpose Service Robot tasks.

These plans can be represented in what we call *Plan* file format, which can be used to be read by humans and also to be debugged with our visual interfaces. *Plan*s can also be considered *Behaviours*.

Initially, easy tests may be graphically solved by using our block-like interface, once tests require a more cognitive approach other engines can be used.

We use the following external sources of software:

[9] Publication under review.

– The Robot Operating System[10] **ROS** a collection of open source tools, libraries, and conventions for developing robot behaviour across a wide variety of robotic platforms.
– Machine learning algorithms from **Dlib**[11] a collection of open source machine learning algorithms that can be in a wide range of domains including robotics, embedded devices, mobile phones, and large high performance computing environments.
– Keras Python API[12] for enabling Deep Learning models on Pepper Robots.

Although our architecture supports external and cloud services we do not intend to use them at competition many due to the network traffic which typically interferes. Instead we prefer to run all behaviours on-board the robot.

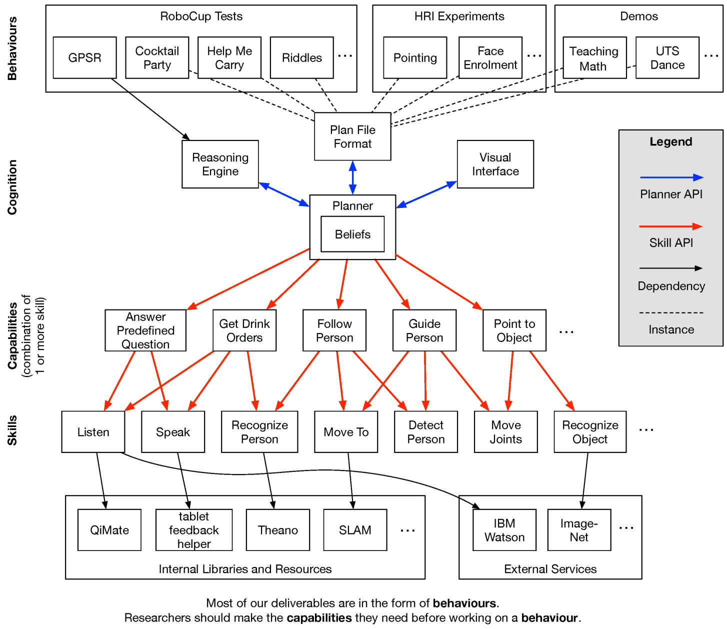


**Fig. 2.** Software Architecture.

## 4 Reusability for Other Research Groups

Our research lab has placed public dissemination and re-usability as a priority in its research efforts. New projects are, by default, made publicly available.

[10] Available from `http://www.ros.org/`
[11] Available from `http://dlib.net/`
[12] Available from `https://keras.io/`

Our research lab Github profile is growing rapidly hosting 39 repositories, in addition to the 230 repositories associated with the individual Github profiles of lab's members.

We currently plan to continue our open position on code release as part of the RoboCup@Home campaign and will develop and release stable and documented code around the following themes:

1. A rapid experimentation and development framework based on Python, ROS and a range of web toolkits.
2. Cognitive architectures for intelligent social and socially-motivated behaviour.
3. Behavioural and gestural control system that combine web interfaces with intelligent behaviours.
4. Visual systems optimised for fluent social behaviour.
5. Visual tools for easy debugging of complex behaviours.

As the robot platform Pepper is standardised so the re-usability is assured. Also the ROS software components can be shared with other robots.

The software development methodology used in our research lab is also a topic of active research and is to be shared with the league too soon.

## 5 Applicability of the Approach in the Real World

Our research is conducted with a direct and immediate focus on real-world applications. We conducted research with Australia's largest bank and with other major commercial partners. Currently, we are investigating the deployment of social robots applications in public spaces by collaborating with Australia's government bodies and public hospitals. This research agenda is intended to have commercial applications and affords us venues to test research in real world applications, thus translating research into societal benefits. Our strategic web of partnerships enables us to do this without impacting our ability to publish original research and make our source code available to other research groups around the world.

Also RoboCup@Home focuses in real life home environment situations so every skill developed for the contest has a direct application in the real world.

## 6 Conclusions and Future Work

Our team has more than 15 years experience in robotics research and development, with a particular focus on social robots co-existing in human-centric spaces and co-operating with people. We have participated at RoboCup since 2003 and the recognise that @Home League offers unparalleled opportunity to contribute and to test our social robot applications.

In addition, Sammy Pfeiffer is an active member of the Technical Committee for second year in a row. He is looking forward to working with committee members and team leaders to improve the league and make it progressively more sociable.

Our team's aim is to include focus on the social and HRI aspects in the upcoming competition for this league, so that RoboCup@Home can positively enrich specific areas of robotics challenges that it was designed to meet.

Future work will include research oriented to further develop and extend the capabilities of our novel skill-based oriented system, BUNJI, to allow even more agile development embracing continuous integration to ensure robustness. Also empowering more human-like approaches enabling robots to take decisions and reactively change plans to solve unexpected situations.

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