# Software Development for Autonomous and Social Robotics Systems

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**Abstract.** One of the core features of social robotics system is a physical interaction between humans and humanoid robots. This provides additional challenges, both from safety and usability prospectives. When dealing with human-robot interaction, human safety has the highest priority. While in industrial environment we have robot cells to protect humans, in social robotics, that we consider, physical contact is possible, as well as other interactions, with consequences that might be in psychological areas. For example, the conversation with children might have different requirements in comparison to the conversation with adults, the behavioural assumptions might be different, etc. This paper summarises the core results of a project on social robotics system, where an autonomous humanoid robot guides visitors through a lab tour. The results of our work were implemented on the humanoid PAL REEM robot. The implementation includes a web-application to support the management of robot-guided tours. The application also provides recommendations for the users as well as allows for a visual analysis of historical data on the tours.

## 1 Introduction

Social robotics, autonomous agents and autonomous robots, are emerging research areas. Over the last years there were many publications on applications of robotics for healthcare and rehabilitation, household service, healthcare and rehabilitation, companionship, etc., cf. [34]. The core function of social robots is assisting people through social interaction, in many cases involving also a physical interaction. A highly cited[1] paper of Feil-Seifer and Mataric [13] defines the concept of socially assistive robotics. Another highly cited[2] paper of Duffy [9] discusses the use of anthropomorphic paradigms to augment the functionality and behavioural characteristics of a robot use of human-like features for social interaction with people.

To understand the impact and capabilities of autonomous robots, it is crucial to identify, observe and measure human-robot interaction (HRI), as well as to

[1] 462 citations according to the Google Scholar, retrieved 20 December 2017.
[2] 592 citations according to the Google Scholar, retrieved 20 December 2017.


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develop systems that support these observations and measurement. The focus of our project is on social robotics: analysis of interaction between humans and humanoid robots, as well as the corresponding support in the development and maintenance of humanoid robotics systems that are acting autonomously.

The work was conducted in collaboration with Commonwealth bank (CBA) under support of the Australian Technology Network (ATN). This project was a part of the ATN CBA Robotics Education and Research program, and continued our previous research on the topic of social robotics using a humanoid PAL REEM robot to conduct the experiments: The first project was dedicated to the development of a general framework for a REEM guided tour as well as its implementation for the REEM robot, cf. [7].

*Contributions:* The current project extends the developed framework by new features, such as (1) providing a web-based application for navigating the robot during the phase of collecting the spatial information, (2) creating and editing the tour files in a user-friendly manner, (3) providing recommendations for the users, as well as (4) allowing for a visual analysis of the data on previous tours. In this paper we present a solution that allows lab assistants to interact with the robotics system without having any technical knowledge about the system. It can be operated by any exhibition, lab staff member or social psychologist. The paper is based on a technical report [31].

The project presented in this paper is a part of the RMIT University activities on enhancing learning experience by collaborative industrial projects [6,25,28–30]. The core results of our previous project on social robotics are presented in [7]: We focused on the Lab tours use case, where the robot takes guests on tours of our Innovation Labs and answers related questions. The framework presented in [7] is based on a formal framework for modelling and analysis of autonomous systems and their compositions [27], and can be applied to any kind of guided tours, as changing the application domain would mean changing only on the content of information provided about exhibits. In the project that we present in this paper, we went further to extend the framework with web-based interface providing many useful features. While the old version with the voice commands is more human-oriented, the new web interface can be useful for noisy environments.

*Outline:* The rest of the paper is organised as follows. Section 2 presents related work. The architecture of the developed system as well as its core functionalities are introduced in Sect. 3. Section 4 summarises the paper and introduces directions of our future work.

## 2 Related Work

Duffy et al. [10] presented the concept of Social Robot Architecture, which integrates the key elements of agenthood and robotics in a coherent and systematic manner. The ethical and social implications of robotics were discussed by Lin et al. in [18]. Young et al. [33] examined social-psychology concepts to apply them to the human-robot interaction.

Eyssel et al. [12] presented a case study where they analysed the effects of robot features (human-likeness and gender) and user characteristics on the HRI acceptance and psychological anthropomorphism. Salem et al. [23] analysed the effects of gesture on the perception of psychological anthropomorphism, by conducting a case study using the Honda humanoid robot. Trovato et al. [32] conducted a cross-cultural study on generation of culture dependent facial expressions of humanoid robot. Sabanovic et al. [22] discussed the use of observational studies of human-robot social interaction in open human-inhabited environments. Klein and Cook [15] analysed and compared the findings in the UK and Germany on robot-therapy with emotional robots as a treatment approach for people with cognitive impairments.

There were also a number of surveys and literature reviews on the related topics. A survey on social robots for long-term interaction was presented in [17]. A systematic review on application of social robotics in the Autism Spectrum Disorders treatment was presented in [21]. Cabibihan et al. [5] presented a survey on the roles and benefits of social robots in the therapy of children with autism.

Alemi et al. [1] examined the effect of robot assisted language learning on the anxiety level and attitude in English vocabulary acquisition amongst Iranian EFL junior high school students. The results demonstrated that application of social robotics in this context can increase learners' engagement as well as satisfaction from the education process. Shimada et al. [24] used a social robot as a teaching assistant in a class for children's collaborative learning, and concluded that a robot can increase children's motivation, but cannot increase their learning achievement. Glas et al. [14] introduced a design framework enabling the development of social robotics applications by cross-disciplinary teams of programmers and interaction designers.

From computer science point of view, our social robots are software agents. Software agent is a running computer program which is performing tasks for a user, i.e. on behalf of him. In order to do it, agent should have knowledge about the tasks that it is expected to execute. Those are intelligent systems that could be autonomous, work with humans, or other agents. If mobile robots are involved, i.e., capabilities of performing motion, apart from those task operational duties, they have to sense and navigate environment. An adaptive roadmap approach, for autonomous robots path planning, is already investigated comprehensively, as given in [11].

## 3 System Architecture and Core Features

The architecture of the proposed system is demonstrated in Fig. 1. The core physical component of the system is the REEM robot controlled by the Robotics Operating System (ROS) to enable precise control from high-level programs. ROS provides services for Web-ROS communication, cf. Fig. 2: ROS side can launch a service while the web-interface can call a service. In this project, we focused on the Tour and Motion Services.

Like in our previous project [7], our work was divided into two phases:

- Phase 1 was conducted in the RMIT University VXLab (Melbourne, Australia). The introduction to the VXLab facilities can be found in [3,4,26]. The web-based interface was developed using a simulated environment provided by a ROS robot software development framework.
- Phase 2 was conducted in the CBA Labs (Sydney, Australia). A number of experiments were conducted to apply the developed web-based interface to a real REEM robot and to simulate the scenario when an operator prepares an exhibition/lab tour and executes it, both in simulated environment and on a real robot.

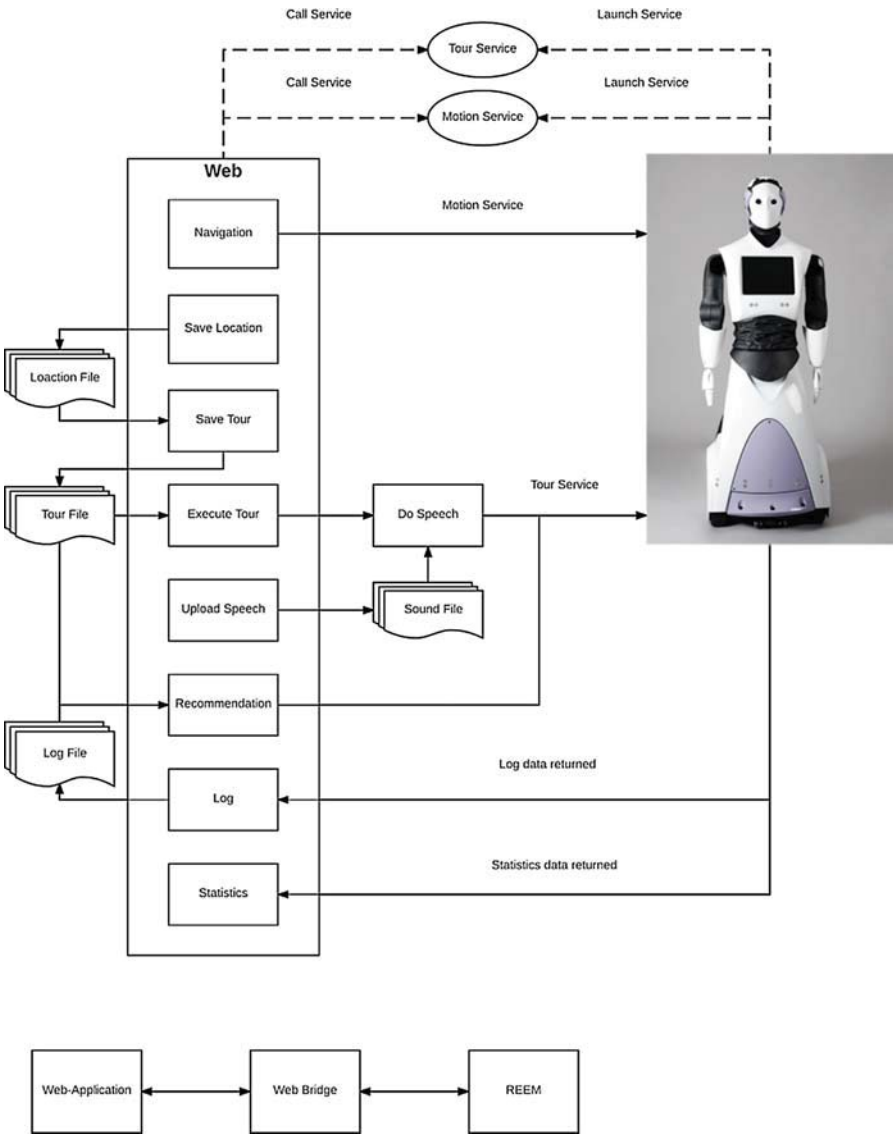



**Fig. 1.** System Architecture

To develop the web-based interface, we applied React.js, an open-source JavaScript library. To execute the JavaScript code server-side we applied Node.js, an open-source JavaScript runtime environment. Node.js provided the management of dependencies to certain web packages that were required for certain features to be used such as UI elements and the ROS-bridge API.

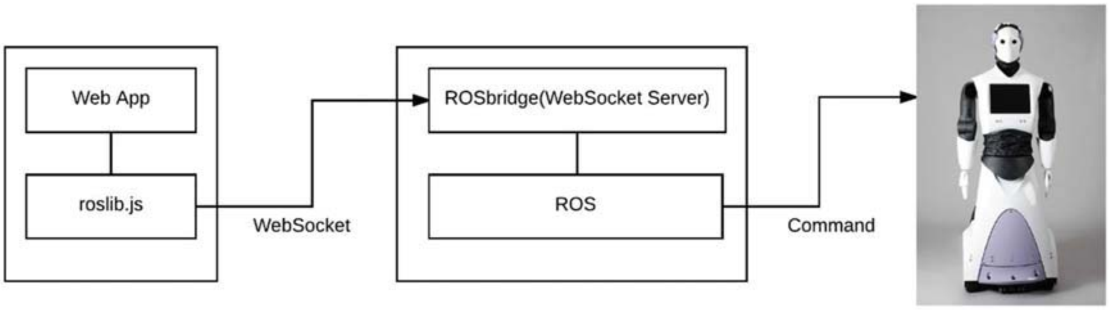



**Fig. 2.** Command flow within the system

ROS (Hydro Medusa) was used as the robot operating system that provides interfaces to the REEM robot's sensors, motors, actuators and speakers, by utilising Python and C++ libraries. The robot gesture, movement and navigation functionalities relied on ROS libraries. The experiments were conducted under the Ubuntu 12.04 platform. The Gazebo simulator 2.2.3 was used as the simulation environment to test the capabilities of the robot. During simulation, the movements of the robot were portrayed through control of the RViz visualisation. Converting text to speech was conducted using

- IBM Watson text-to-speech (TTS) service for the simulation, and
- on-board Acapela TTS for the experiments on the real robot.

In the simulation environment, TTS relied on Watson for wave files generation and then playing them back through sound player. When deploying on the actual robot this process is handled by Acapela, a TTS engine from Acapela Group.

Figure 3 presents the control page, where the movements of the robot can be controlled by using the corresponding menu items. This provides the functionality necessary to create the lab tours: to navigate the robot, and to store the current locations of the robot.

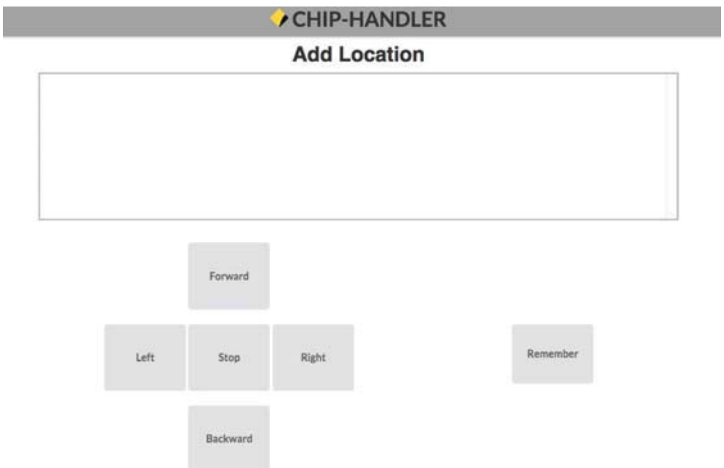
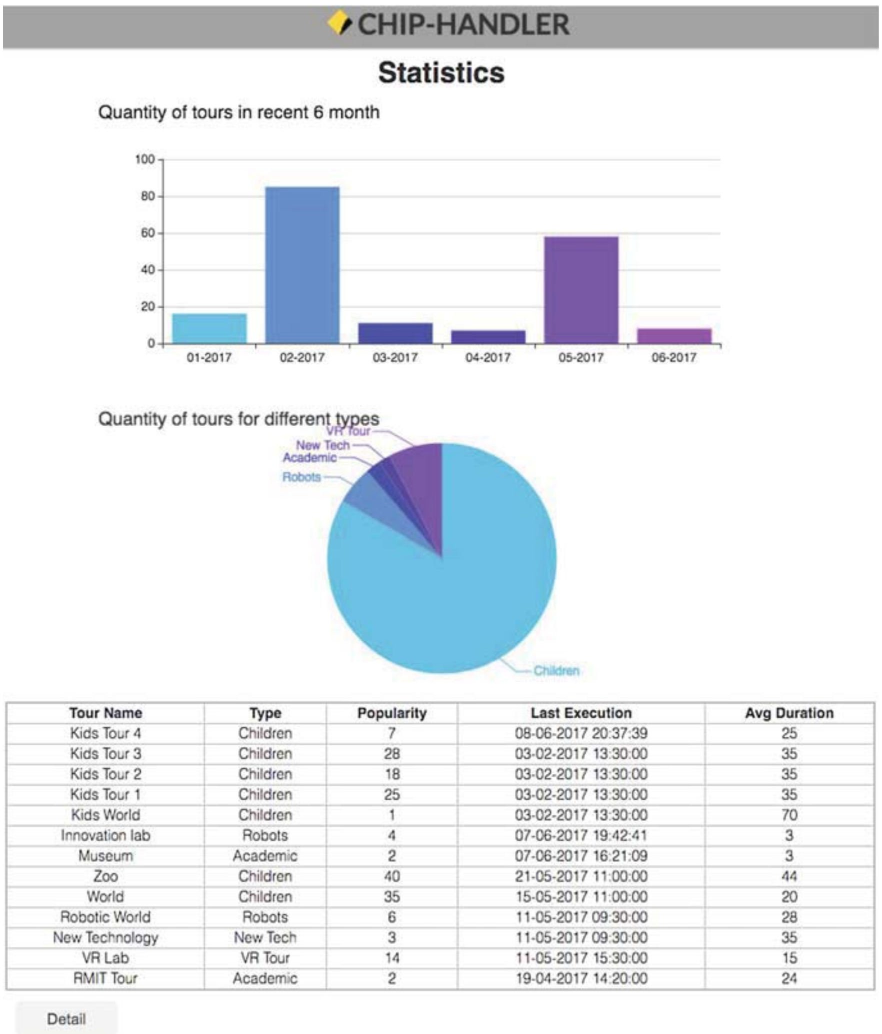



**Fig. 3.** Navigation management

The tour management page allows to display all the existing tours and all the locations within each tour, as well as to manage them. We can edit the content of an existing tour, add new tours, copy existing tours, search for particular tours or locations, etc. The web application also provides the functionality to edit the information on stored locations. The text within the description field will be a part of the speech within the guided tour: the *text-to-speech* module of the robot system will transform the text to the speech when the robot approaches the location.

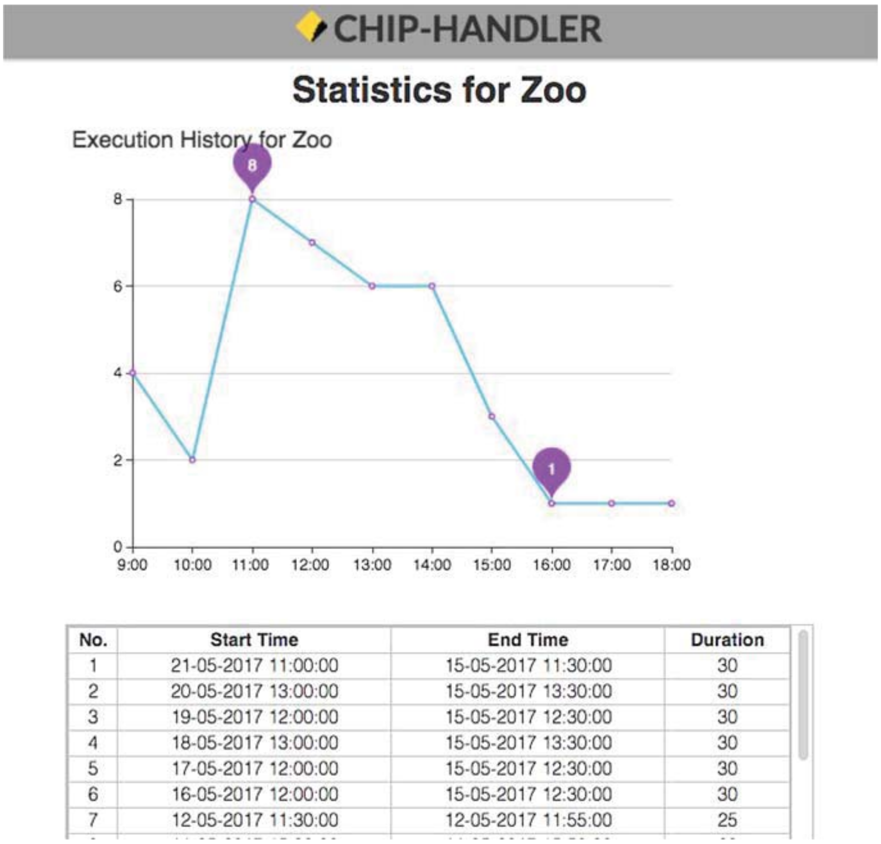
Figure 4 presents an example of the visualisation features that are provided by the application: (1) statistics on the tours within the previous 6 months, (2) the distribution of he tours by their types, both in tabular and graphical format. The users can also obtain more detailed information on a particular tour, cf. Fig. 5 for an example. Figure 6 demonstrates how the developed system provides recommendations to the users based on the tour popularity.



| Tour Name | Type | Popularity | Last Execution | Avg Duration |
|---|---|---|---|---|
| Kids Tour 4 | Children | 7 | 08-06-2017 20:37:39 | 25 |
| Kids Tour 3 | Children | 28 | 03-02-2017 13:30:00 | 35 |
| Kids Tour 2 | Children | 18 | 03-02-2017 13:30:00 | 35 |
| Kids Tour 1 | Children | 25 | 03-02-2017 13:30:00 | 35 |
| Kids World | Children | 1 | 03-02-2017 13:30:00 | 70 |
| Innovation lab | Robots | 4 | 07-06-2017 19:42:41 | 3 |
| Museum | Academic | 2 | 07-06-2017 16:21:09 | 3 |
| Zoo | Children | 40 | 21-05-2017 11:00:00 | 44 |
| World | Children | 35 | 15-05-2017 11:00:00 | 20 |
| Robotic World | Robots | 6 | 11-05-2017 09:30:00 | 28 |
| New Technology | New Tech | 3 | 11-05-2017 09:30:00 | 35 |
| VR Lab | VR Tour | 14 | 11-05-2017 15:30:00 | 15 |
| RMIT Tour | Academic | 2 | 19-04-2017 14:20:00 | 24 |



**Fig. 4.** Analysis of the data on the previous tours




| No. | Start Time | End Time | Duration |
|---|---|---|---|
| 1 | 21-05-2017 11:00:00 | 15-05-2017 11:30:00 | 30 |
| 2 | 20-05-2017 13:00:00 | 15-05-2017 13:30:00 | 30 |
| 3 | 19-05-2017 12:00:00 | 15-05-2017 12:30:00 | 30 |
| 4 | 18-05-2017 13:00:00 | 15-05-2017 13:30:00 | 30 |
| 5 | 17-05-2017 12:00:00 | 15-05-2017 12:30:00 | 30 |
| 6 | 16-05-2017 12:00:00 | 15-05-2017 12:30:00 | 30 |
| 7 | 12-05-2017 11:30:00 | 12-05-2017 11:55:00 | 25 |

**Fig. 5.** Analysis of the data on the tour *Zoo*

## 4 Discussion and Conclusions

In this paper, we presented the core results of the project on software development for social robotics systems: We developed a web-based solution that supports the management of robot-guided tours, including the collection of the spatial information for the tours within noisy environments. To summarise, the developed web-based interface provides the following features:

- Navigate the robot,
- Store the current locations of the robot,
- Manage saved locations,
- Create customised tours based on saved location,
- Embed speeches for customised tours,
- Store information about a customised tour, such as the tour type, duration, etc.,
- Provide recommendations for the users, and
- Visual tool to analyse the data on previous tours.

The results of our work were implemented to the humanoid PAL REEM robot, but their core ideas can be applied for other types of humanoid robots and autonomous systems.

We plan our future work on this project in the following directions:

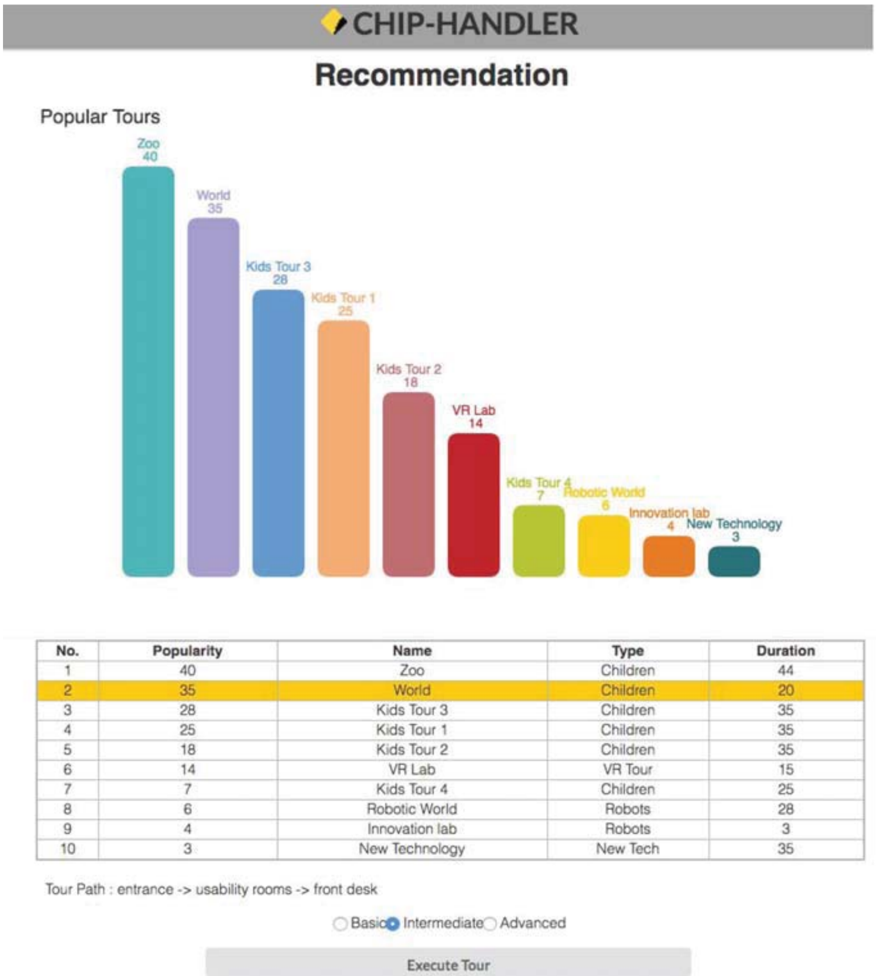



**Fig. 6.** Recommendations for the users based on the tour popularity

- To embed into the developed REEM framework the efficient testing methods, e.g. [16,19,20] as well as the model-based hazard, impact analysis and optimisation methods [2,8];
- To apply the developed framework to another type of ROS-based robot, Baxter, hosted in the RMIT University VXLab;
- To expand the developed guided tour features to involve game activities, as this would make the tours for children more entertaining and increase the children engagement;
- At this stage of our research, we have concentrated on a single intelligent robot working in human environment. Next step will be to explore scenario when our intelligent robot exists and perform tasks in the environment where, apart from humans, we have other intelligent agents as well. We will consider multi-agent systems for various applications.

Finally, but extremely important, we will comprehensively investigate safe Human-Robot interactions, current strategies and methods in practice, and possibly come up with the new solutions for the particular work environments and scenarios.

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