Utilizing Bluetooth Low Energy for human-robot interaction

Marcus M. Scheunemann[1], Kerstin Dautenhahn[1,2], Maha Salem[1], and Ben Robins[1]

***Abstract*— It remains one of the main challenges for mobile robots in a human inhabited environment to interact with surrounding individuals. Usually, recognizing touch gestures, perceiving proximity information, or distinguishing between individuals is both a cost and configuration intensive task. In this demonstration we utilize inexpensive Bluetooth Low Energy (BLE) devices attached to the robot and participants. We derive information of participants by measuring the received signal strength (RSS) between BLE devices. The system's flexibility is shown by using a proprietary mobile spherical robot. Three proof-of-concept demonstrations will be presented, each refers to one information factor about individuals in the surrounding environment: A) proximity, B) touch, and C) who is interacting with the robot. The audience can observe the robot's output data of the raw RSS to surrounding BLE devices attached to wristbands worn by interacting participants.**

I. MOTIVATION

Many sensors are applied to enable human-robot interaction (HRI) scenarios. For example, force resistance sensors (FSR) for recognizing touch gestures, laser or ultra-sound for perceiving proximity information of moving objects in the closer vicinity, and camera or tracking systems for providing the robot with information about the surrounding individuals.

All these sensors are well established, thoroughly investigated and successfully used in many applications. However, we felt that all of these systems have shortcomings with regard to specific applications.

For example, we are in the process of utilizing a mobile rotating robot with proprietary hardware for robot-mediated therapy for one or more children with autism. To enable adaptive interaction, this robot needs to receive touch and proximity information of the surrounding children and should recognize which child is interacting with it. The proprietary hardware of the used robot prevents us from utilizing the built-in board and attach sensors to it. Thus, we were seeking for a system architecture to perceive information about surrounding individuals independently.

Gaining proximity information with laser/ultra-sound or a camera system mounted on a fast and wobbly locomoting robot is challenging. In addition, using a camera or tracking system to distinguish between interacting children is, from our experience, difficult. First, those systems need to be configured. Children might need to stand still to calibrate the system or wear specific clothes with trackables. Both options are distracting and yield a huge effort to conduct studies with the children.

[1]All authors are with Adaptive Systems Research Group, University of Hertfordshire, AL10 9AB, UK marcus@mms.ai

[2]IEEE Senior Member

Some HRI experiments (as the one mentioned previously) may benefit from being conducted in a natural environment. Applying a tracking system to such an environment in an unobtrusive manner is at least a cost intensive task.

We thus were seeking for a simple easy applicable technology. We decided to explore the new standard BLE and exploit the RSS between BLE devices to enhance HRI scenarios with touch gestures, proximity information and provide the robot with the capability to distinguish between interacting individuals.

II. BENEFITS OF BLE

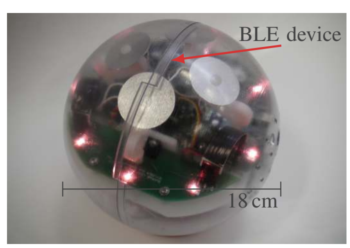
In contrast to previous Bluetooth versions and WiFi, BLE only needs little energy. This is mostly due to the small payload of the protocol since it was not intended for communication or streaming applications. Moreover, the small payload makes it possible to discover BLE devices very quickly. Therefore, BLE devices can be positioned flexibly due to their small size yielded by the small power source of a coin cell battery, while quick scanning allows the system to obtain RSS data every few milliseconds rather than seconds.

In addition, BLE is used in a growing number of mobile phones, smart/fitness wristbands/watches. It integrates in our everyday life, making it ideal to be exploited as an additional sensor source for HRI experiments.

III. SYSTEM ARCHITECTURE

This section briefly describes the components, the demonstration setup, and the advantages. For a detailed overview and a proof-of-concept evaluation please refer to [1].

A. Components



(a) The robot platform

(b) BLE components

Fig. 1. (a) The mobile robot platform QueBall can be moved back/forth and tilted left/right. It emits sound, colors and detects touch (the four circle objects on top are the touch sensors). (b) Self-powered and configurable advertising beacon to be attached to people (left); a central BLE device scans for surrounding peripherals RSS (right).

Figure 1a depicts the used mobile rotating robot QueBall. It can move forward and backward, and a weight attached to the chassis can tilt it left or right. The chassis tends to point upright and it is equipped with LEDs and touch sensors. Figure 1b shows two different BLE devices. The left device is a BLE beacon. It can frequently advertise a predefined payload (i.e. its ID). The right device is a central BLE device. It has a processor, is programmable, and the full BLE stack is implemented.

B. Setup

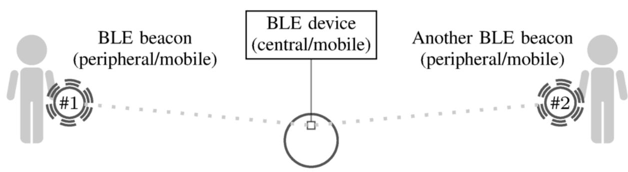


Fig. 2. A central BLE device is used to passively scan for advertisements of peripheral BLE devices. People are equipped with one advertising BLE device. The central device computes packages with RSS data and ID of received advertisements and provides the information to an external notebook wirelessly.

As depicted in Figure 2, BLE beacons attached to the participants emit advertisements. In the demonstration, we place the beacons in generic pocket wristbands. The beacons are configured to advertise their ID roughly every 100 ms. The independent central BLE device is mounted to the robot. It scans for advertisements of surrounding BLE beacons. It computes their ID and the RSS. Figure 3 provides a small impression of a beacon being moved away from the central device. It can be seen that a close beacon might be distinguished from a more distant one.

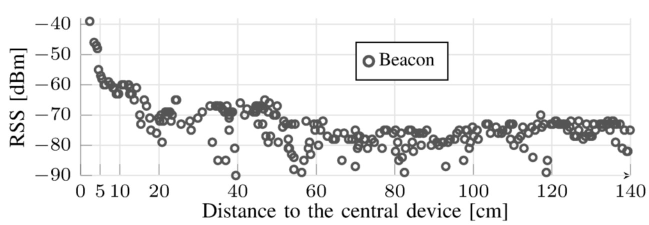


Fig. 3. A beacon is constantly moved away from the central device. The plot shows the RSS of that beacon measured by the central BLE device.

An external machine is connected to the central BLE device. It gets ID/RSS information for further computation and for controlling the robot accordingly.

C. Advantages

Proof-of-concept evaluations suggest that the system can be used to determine the three information factors to a certain degree [1]. However, field trials still need to be conducted and evaluated.

We propose that the system can support quick prototyping of HRI experiments. The technology can be set up quickly and independently of the robot platform. Thus, information about persons in the robot's vicinity can be obtained easily. For this demonstration, we focused on three information factors: A) proximity, B) touch and C) distinguishing between humans.

The systems architecture is independent from the built-in board and can be easily applied to various kinds of objects. Due to its low-power consuming capabilities, one can also think of applying the central device (powered by a coin cell) to a static object and gain additional knowledge about the proximity of people to different objects.

In addition, there is only little configuration needed. To obtain the mentioned three information factors, the only thing to do is to assign a specific ID to the beacons. Furthermore the small devices can be flexibly placed and yield little obtrusion. Thus, we hope that more experiments can be easily conducted outside a laboratory setting.

IV. DEMONSTRATION

An impression of the intended demonstration is provided in a video on `http://mms.ai/BLE4HRI` [2].

We plan to bring the mobile robot and several BLE beacons/wristbands. We will then present how the system architecture can be used to derive information about touch and proximity of surrounding individuals and distinguish between them. Please refer to the section above or to [1] for more details.

We also intend to plot the ID/RSS data on a screen (as can be seen in the video) so people may get a better overview of the possibilities and shortcomings of using BLE for HRI. Depending on the possibilities and time granted, people are welcome to test the system capabilities on their own.

The architecture is in an early stage and thus we hope that a discussion about further enhancements will evolve. For example, only using the raw RSS data is very prone to occlusions. When a beacon is covered by body parts, the robot most likely will not perceive its signal (or a very weak one). We overcome this issue by using a sliding window of some milliseconds. Since the RSS is usually underestimated rather than overestimated, we only consider the maximum value of that window [1]. Although this yield promising results, an exchange of experiences to make the system more general and robust (while keeping its flexibility) are more than welcome.

We expect the system to be used for rapid prototyping of experiments. For example, rather than utilizing/configuring external camera systems, it is easy to attach the beacon to the participant (or use an existing source like a mobile phone, smart watch, etc.). This can be done in an unobtrusive way, and future developments will further decrease the size of BLE devices. Of course, we are more then interested to collaborate with people who intend to adapt the technology for prototyping purposes or in other experimental settings.

References

[1] M. M. Scheunemann, K. Dautenhahn, M. Salem, and B. Robins, "Utilizing Bluetooth Low Energy to recognize proximity, touch and humans," in *2016 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, Aug 2016, pp. 362–367.

[2] M. M. Scheunemann, "BLE4HRI project page," Online, June 2016. [Online]. Available: http://mms.ai/BLE4HRI