

# An intent-based approach for creating assistive robots' control systems

Tomasz Winiarski  
Warsaw University of Technology,  
Institute of Control and  
Computation Engineering  
Warsaw, Poland,  
Email: tomasz.winiarski@pw.edu.pl

Wojciech Dudek  
Warsaw University of Technology,  
Institute of Control and  
Computation Engineering  
Warsaw, Poland

Maciej Stefańczyk  
Warsaw University of Technology,  
Institute of Control and  
Computation Engineering  
Warsaw, Poland

Łukasz Zieliński  
Warsaw University of Technology,  
Institute of Control and  
Computation Engineering  
Warsaw, Poland

Daniel Giełdowski  
Warsaw University of Technology,  
Institute of Control and  
Computation Engineering  
Warsaw, Poland

Dawid Seredyński  
Warsaw University of Technology,  
Institute of Control and  
Computation Engineering  
Warsaw, Poland

**Abstract**—The current research standards in robotics demand general approaches to robots' controllers development. In the assistive robotics domain, the human-machine interaction plays a substantial role. Especially, the humans generate intents that affect robot control system. In the article an approach is presented for creating control systems for assistive robots, which reacts to users' intents delivered by voice commands, buttons, or an operator console. The whole approach was applied to the real system consisting of customised TIAGo robot and additional hardware components. The exemplary experiments performed on the platform illustrate the motivation for diversification of human-machine interfaces in assistive robots.

**Index Terms**—robot control, assistive robots, intents handling, framework

## I. INTRODUCTION

The current demographical processes demand new technologies to support a large number of Elderly or disabled persons. Assistive and social robots respond to it [1], [2]. Although some aspects of assistive robot development have a general nature (e.g. low-level motor control), others are more specific. Human-machine interfaces (HMIs) play a vital role in practical applications of assistive robots. Human-machine interaction is being investigated both for mobile robots [3] and stationary HMI devices [4]. One of the main problems encountered is to maintain reliability of communication.

The goal of our work is to at first determine appropriate HMIs to provide robust multimodal interaction of a human and robot-based system. We concentrate on the armless systems, as they are expected to dominate the market, because of

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the relatively low price. Efficient research demands frameworks [5] that reduce the time to develop software by code reuse and utilisation of supporting tools. Hence, we propose an intent based general approach to assistive robot's controller development that takes into account the current technologies that support the efficient usage of the previously chosen HMIs.

The research process started with the determination of the HMIs based on the analysis of the existing robotic platforms (sec. II). The general structure of the based system is depicted in sec. III-A, while the main aspects of its behaviour in sec. III-B. Sec. IV presents a practical application of our approach, i.e. the system build basing on TIAGo robot. The exemplary experiments illustrate the importance of human-machine interface multimodality. The paper is concluded in sec. V.

## II. SURVEY OF ROBOTIC PLATFORMS AND THEIR HMIs

A review of 58 different robotic platforms was conducted. The functions of examined robots varied from entertainment platforms, through assistive services, to helping people with day-to-day activities and supporting Elderly (Tab. I).

The study inspected the robots for the chosen features:

- 1) possession of the built in, interactive, touch-screen tablet,
- 2) ability to speak,
- 3) ability to recognise voice commands,
- 4) possession of physical buttons and their placement.

Out of 58 examined robotic platforms:

- 30 possessed the specified tablet,
- 36 were able to speak,
- 32 were capable of voice commands recognition,
- 8 possessed some physical buttons (emergency buttons are not counted, because they are not the regular communication medium) and only one robot had buttons that could be accessed from all sides of the robot.

No.	Robot name	Producer	Interactive tablet	Text to speech	Voice recognition	Physical buttons*	No.	Robot name	Producer	Interactive tablet	Text to speech	Voice recognition	Physical buttons*
1	Oro	ROBOT-ERA	✓	✓	?	R	31	HSR	Toyota	X	✓	✓	X
2	Coro	ROBOT-ERA	✓	✓	✓	X	32	MARIO	MARIO Project	✓	✓	X	X
3	Doro	ROBOT-ERA	✓	✓	✓	X	33	VirtualME	CrossWing Inc	✓	X	X	X
4	MAGGIE	Robotics Lab - Universidad Carlos III de Madrid	✓	✓	✓	X	34	AMIGO	Eindhoven University of Technology	X	✓	✓	X
5	Ferry	Paaila	?	X	X	X	35	AMY A1	AMY Robotics	✓	✓	✓	X
6	Pati	Paaila	✓	✓	✓	R	36	ARMadillo	RoboTiCan	✓	X	X	X
7	Ginger	Paaila	X	✓	✓	X	37	Fetch	Fetch Robotics	X	X	X	X
8	Care-O-bot 3	Fraunhofer IPA	✓	✓	✓	X	38	ForteRC	Ingeniarius, Ltd.	✓	X	X	X
9	Care-O-bot 4	Fraunhofer IPA	✓	X	✓	X	39	Sunbot-II	Siasun	X	✓	✓	X
10	Relay	Savioke	✓	X	X	X	40	Sunbot-III	Siasun	✓	✓	✓	X
11	Stevie	Trinity College Dublin	X	✓	?	X	41	RB-1	Robotnik Automation S.L.L.	X	X	X	X
12	HOBBIT	Hobbit	✓	✓	X	X	42	RP-VITA	CORDAMED	✓	X	✓	X
13	Zenbo	ASUS	✓	✓	✓	X	43	i-foot	Toyota	X	X	X	R
14	I-do	KUKA	X	X	X	X	44	TUG Exchange	Aethon	X	✓	X	X
15	Aibo	Sony	X	X	✓	X	45	TUG T3	Aethon	X	✓	X	X
16	CHiP	WowWee	X	X	✓	X	46	TUG Drawer	Aethon	X	✓	X	✓
17	Arti	Warsaw University of Technology	X	?	?	X	47	TUG for Hospitality	Aethon	✓	✓	X	X
18	Temi	Temi	✓	✓	✓	X	48	K5	Knightscope	X	✓	X	X
19	Robelf	Robelf	✓	✓	✓	?	49	ReMeDi	ReMeDi consortium	X	X	X	R
20	Honeybot	Honeybot	✓	✓	X	R	50	Hugo/GrowMU	GrowMeUp	✓	✓	✓	X
21	Kuri	Mayfield Robotics	X	X	✓	X	51	MOV0	Kinova	X	X	X	X
22	Robot Prison Guard	Kyonggi University	✓	X	X	X	52	CASERO	MLR System GmbH	✓	X	X	R
23	Sanbot Elf	Sanbot Innovation	✓	✓	✓	X	53	RAMCIP	CERTH	✓	✓	✓	X
24	Robina	Toyota	X	✓	✓	X	54	Pepper	SoftBank Robotics	✓	✓	✓	X
25	ROBEAR	RIKEN	?	X	X	X	55	Robovie II	ATR	X	✓	✓	X
26	Sunbot-I	Siasun	X	✓	✓	X	56	PeopleBot	Adept	X	✓	✓	X
27	Tiro Robot	Hanool Robotics Corp	✓	✓	✓	X	57	FLASH/ FLASH MK II	Wrocław University of Science and Technology	X	✓	✓	X
28	Benebot	ECOVACS ROBOTICS	X	✓	✓	R	58	LoweBot	Lowe's Innovation labs	✓	X	✓	X
29	REEM	PAL Robotics	✓	✓	X	X							
30	TIAGo	PAL Robotics	X	✓	✓	X							

\* Emergency stop buttons are not regarded, ✓ – Robot possesses feature, X – Robot does not possess feature, ? – The possession of feature is suggested but could not be confirmed, R – Access to the physical button is restricted because of its location.

**TABLE I.** Review of selected functions for 58 different robotic platforms

Note: in some cases, some of the robot features were not described. Such robots were not included in the above juxtaposition.

The above survey visualises that voice communication and tablets are the main HMIs, while the buttons are absent or used for emergency procedures only. To obtain the highest reliability of voice communication, nowadays the cloud-based services can be used. Although the usage of tablets touch-screen, as the different communication interface to voice, is versatile, we opt for buttons. In comparison to buttons, tablet is bigger, heavier, prone to physical damage. It needs to be charged often, its usage is more complicated, especially for Elderly [6]. The number of assistive robots applications can be handled with buttons, in order to, e.g., call the robot (the appropriate button is located in the home environment), ac-

knowledge the command spoken by the robot, etc. The buttons should be mounted in the proper places to be accessed easily and intuitively. For the convenience of research, development, maintenance or even regular operation, an operator/caregiver console should be included in the system.

### III. GENERAL STRUCTURE AND BEHAVIOUR OF A SYSTEM

Our approach to control system creation is based on the RAPP architecture [7] extended by the Agent types introduced in [8] – a Task Harmoniser Agent and a Task Requester Agent. It is described with usage of EARL [9] – Embodied

Agent-based [10] cyber-physical control systems modelling Language (version 1.1) [11].

### A. Structure

The whole System is decomposed into various types of Agents derived from the general Agent «block» (Fig. 1).

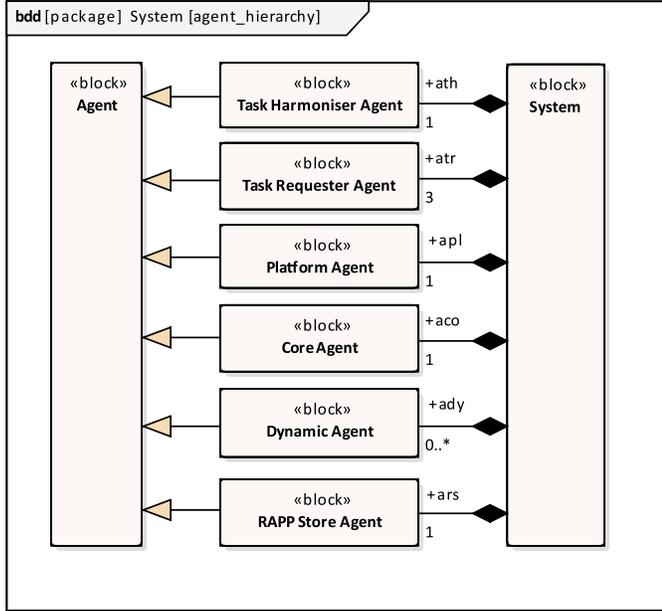


Fig. 1. Agent hierarchy

The Agents instances are the parts of the System with particular names. The permissible communication in the System is shown in internal block diagram (Fig. 2).

1) *Core Agent*: drives the hardware of the robot and provides the services to be called by other Agents:

- navigation configuration and goal set,
- control of neck and torso lift,
- text-to-speech,
- translation of a voice command into an intent.

In the presented System there is one robot operating in the environment, so there is only one Core Agent named *robot/aco*.

2) *Dynamic Agents*: are parts of the System, which utilise services delivered by other Agents in order to perform a task that a particular Dynamic Agent is designed for. A Dynamic Agent interprets data possessed from other Agents and compute control for the robot, guiding it to perform the task implemented in the Dynamic Agent. An exemplary specification of a Dynamic Agent was described in [12]. There can be multiple Dynamic Agents in the System, however, at most one can be initialised at a time.

3) *Platform Agent*: aggregates System-wide computational services. As the Platform Agent from its definition operates in the cloud [13] and has huge computation power and storage space, most of the behaviours requiring high computation power are delegated here. However, some of the computationally complex behaviours have to be done by Agents located

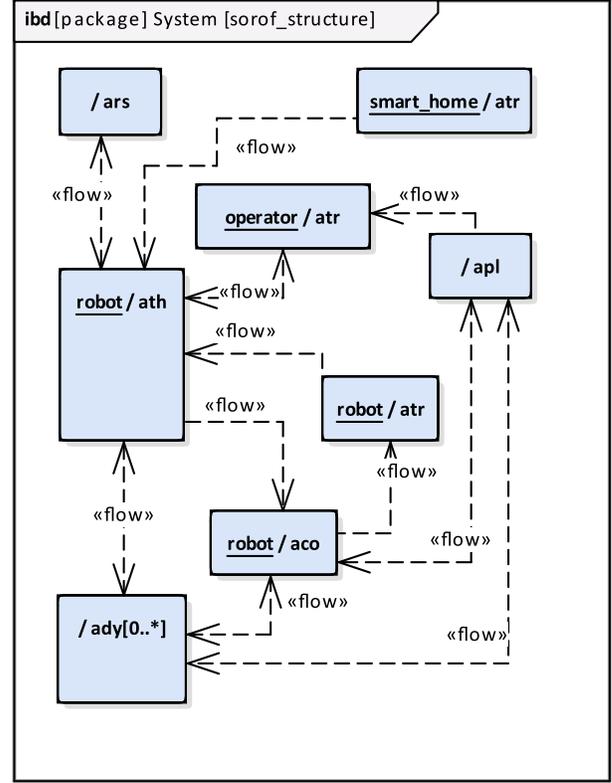


Fig. 2. Inter Agent communication in the System

in the robot computer as they are latency-sensitive or process sensitive personal data. The method of a System behaviours delegation between Agents was presented in [14]. There is only one Platform Agent in the System.

4) *Task Requester Agents*: are parts of the System, which basing on the data from robot's or additional sensors request the Task Harmoniser Agent to perform tasks. There are three Task Requester Agents in the System: *smart\_home/atr*, *robot/atr* and *operator/atr*. The first one is an interface for a smart home platform. It requests tasks basing on the defined rules. The *robot/atr* uses user intents captured by the robot hardware (e.g. microphone), and the *operator/atr* uses an application that is used for robot supervision.

5) *Task Harmoniser Agent*: receives task requests from the Task Requester Agents and schedules Dynamic Agents basing on a specified algorithm (e.g. priorities). The problem of Dynamic Agents scheduling was introduced in [8]. It communicates with RAPP Store Agent in order to download a proper task files implementing a Dynamic Agent. There is one Task Harmoniser Agent in the System named *robot/ath*.

6) *RAPP Store Agent*: keeps files with executable code that implement various tasks available for a System and provides a service allowing to download them.

### B. Behaviour

One of the main aspects of communication between Agents is shown in Fig. 3. At first, an Elderly commands the robot either with voice or with a button (Fig. 4). In the first case,

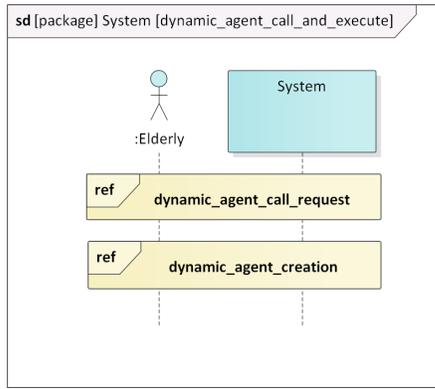


Fig. 3. Dynamic Agent call request and creation

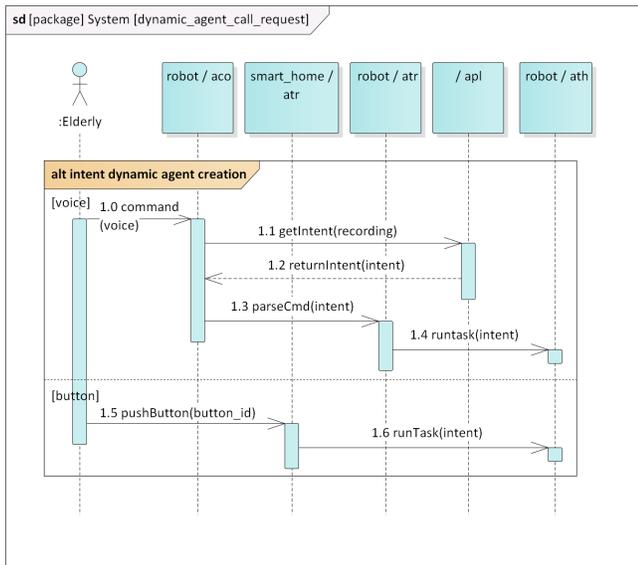


Fig. 4. Dynamic Agent call request

the voice is recorded by *robot/aco* and the recording is sent to */apl*. The Platform Agent runs speech-to-text algorithms and sends back the detected intent to *robot/aco*. An intent represents an interpretation of the voice command. Next, the intent is sent to *robot/ath* via *robot/atr*. In the second case, a button is triggered, and *smart\_home/atr* sends to *robot/ath* an intent related to the button. At this point there are two alternatives (Fig. 5):

- *task/ady* can be created, so task harmoniser *robot/ath* downloads the code of Dynamic Agent *task/ady* from the RAPP Store Agent */ars*. It is done by sending a message from *robot/ath* to */ars*. In response, a message containing the code of *task/ady* is sent in opposite direction and *robot/ath* creates *task/ady*,
- *task/ady* cannot be created, so *robot/ath* sends a message with human-readable description of failure reason to *robot/aco*. If needed, the Core Agent requests text-to-speech from */apl* for the failure reason text. The received

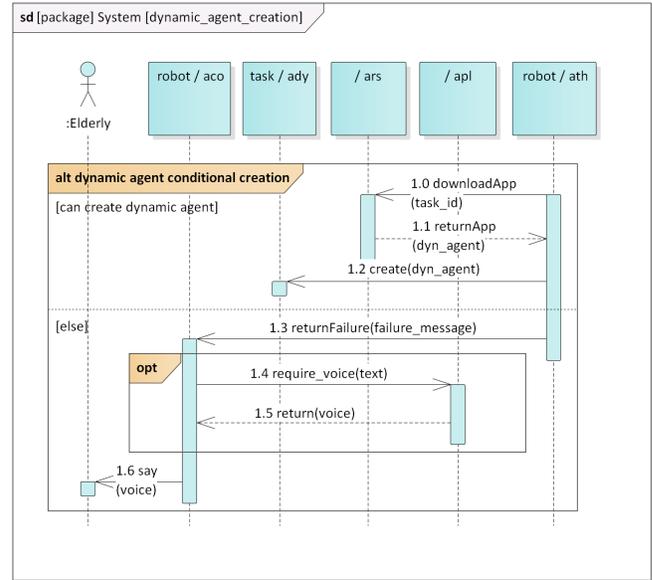


Fig. 5. Dynamic Agent creation

voice response is played back to human.

The possible causes of *task/ady* creation failure are:

- another Dynamic Agent is already running, and it has higher priority than the requested one,
- the detected intent is not a command for creation of a new Dynamic Agent.

In order to avoid repeating text-to-speech */apl* queries, the recordings are cached by *robot/aco* and they can be reused ('opt' frame in Fig. 5).

Another example of communication between agents is shown in Fig. 6. In this case, the dynamic agent *task/ady* initiates a conversation with human by sending a message to *robot/aco*. Text-to-speech, if needed, is realized in */apl*, thus *robot/aco* sends message with text to */apl* and receives back a message that contains a wave file. The voice is played to human. The human says a response, and the recorded voice is processed by */apl* to detect intent, similarly as in the previous example. The intent is then passed through *robot/atr* and *robot/ath* to *task/ady*.

## IV. EVALUATION

### A. Experimental platform

The experimental platform is presented in Fig. 7. TIAGO robot was employed, as it is a robust, ROS-based [15] mobile platform used in modern research projects, e.g. [16], especially when assistive robotics is concerned [17]. An important reason to chose TIAGO was the compatibility of Embodied Agent theory with mobile bases utilising ROS (e.g., a robot with various modes of locomotion [18]). A detailed description of the TIAGO platform and its capabilities are presented in [19]. The robot with its internal PC and all software provided by PAL is specified as a single embodied Agent *robot/aco* (Fig. 7). Due to *robot/aco* internal PC performance limits, an

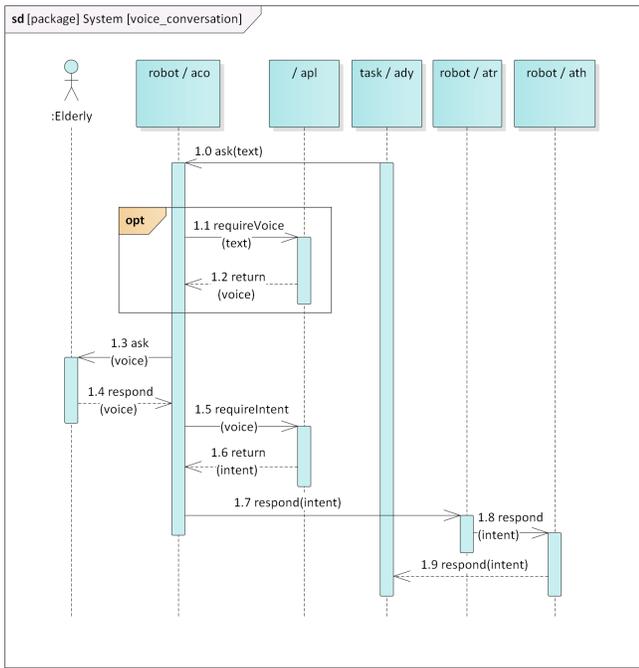


Fig. 6. Voice conversation

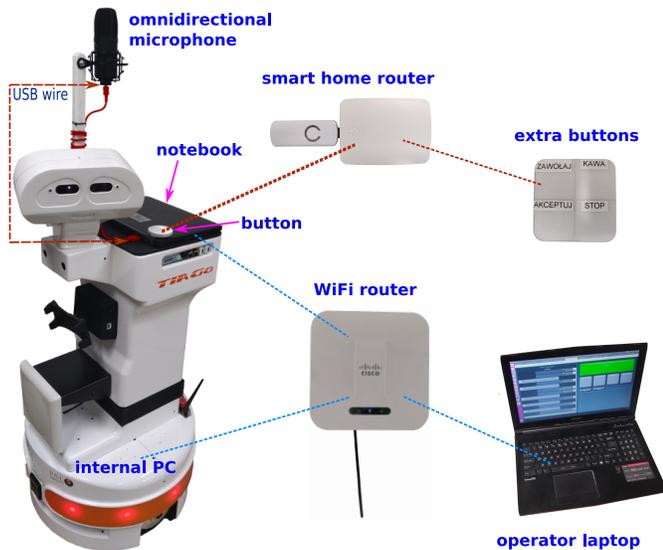


Fig. 7. Customised TIAGo robot and other hardware components involved in practical application

additional notebook was required to perform voice acquisition and high-level task execution. Thus, a part of *robot/aco* Agent responsible for voice processing, and Agents *robot/atr*, *robot/ath* and all */ady* are realised as software (ROS nodes) running on the notebook.

The notebook and the internal PC of TIAGo communicate with each other through wireless network. ROS was used as the main implementation platform. Agent *smart\_home/atr* is composed of devices of smart home that are connected through

wireless network. Dynamic Agents */ady* are implemented using SMACH [20], however, any other framework compatible with ROS can be used.

### B. Exemplary experiments

During the initial tests of the system, some audio capture problems were identified. TIAGo is equipped with a built-in microphone [21], but it is mounted inside the robot's body, close to the head's motor. Stiff mounting of the microphone causes a high level of rumble noises during the movement, which made it almost impossible to recognise speech. To counteract this problem mounting was changed to soft sponge, but limited space inside the robot made it hard to eliminate all noises. Next problem was the long cable connecting the microphone with audio interface. This analogue cable is long and runs parallel to a bundle of high-current power cables, which induces high level of non-uniform noise. Another problem was a low dynamic range of the device. When the amplification was set too low, commands spoken from the bigger distance were ignored. Too high amplification, on the other hand, makes the noises even worse and effects with signal clipping when the user is near the robot.

To cope with those problems an additional microphone was added to the system. It is an omnidirectional device, with digital interface and high dynamic range. To mitigate mechanical noises, it was mounted using rubber bands. The recordings are much cleaner and the overall recognition accuracy went up. There was, however, another problem still occurring. Our testing environment is rather big (almost a 100 m<sup>2</sup> single room). There are also some places, where the high closets stand on the line-of-sight between the robot and the operator. In order to analyse the effect of the room shape and existing obstacles on the audio recognition accuracy word-spotting accuracy test was carried. During the experiment, the robot was static and different operators were trying to trigger the robot using the keyword from 12 different places (Fig. 8). Each of the 5 users said the keyword 10 times in each spot. Keyword spotting was running on both internal and external microphone to compare the results.

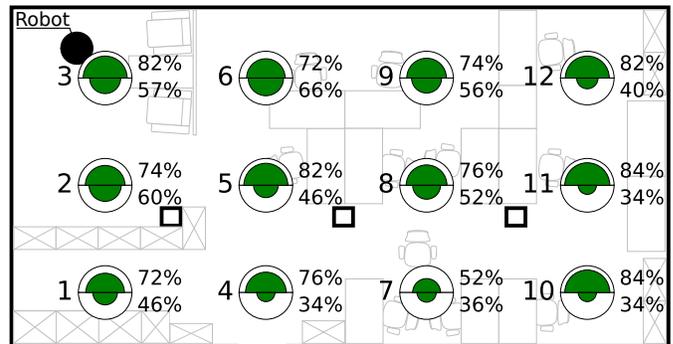


Fig. 8. Comparison of keyword spotting accuracy for two microphones. Top half represents omnidirectional microphone, bottom is built-in device. Position of the robot is depicted with black dot (near the spot 3)

The first visible thing is the much higher overall accuracy of an external microphone. Not only the results are better in every spot, but also they decay less with the distance (see the movie<sup>1</sup>). In some spots the accuracy dropped significantly. For example, the kitchen (spot 1) is separated from the robot with the closets. Structure elements (pillars) also can interfere direct path from the operator to the robot (spot 7). As the effective robot behaviours triggering is crucial, adding alternative resources for this purpose was a natural decision. It was achieved by utilising smart-home infrastructure and expanding it with a buttons. That kind of arrangement guarantees successful human-robot interaction.

## V. CONCLUSIONS

The recent problems in our world let to the conclusion that high effort should be put to assistive robots research not only because of the ageing population of the developed countries. The number of worldwide diseases showed a need to help people that have to be isolated or simultaneously are temporarily or continuously disabled. The robots can radically improve the situation even with simple applications like transportation or guarding. Such robots should communicate with patients in various ways to achieve reliable service of e.g. people that can not operate with hands or have problems with speaking. An approach proposed in this work, helps to develop control systems with the above assumptions. Currently, it is used in the TIAGO robot based system to help the Elderly in the various scenarios that include transportation attendance, guarding, fall prevention and hazard detection [22].

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<sup>1</sup><https://vimeo.com/410844697>