

Feedback is like Cinderella! The important role of feedback when humans and robots are working together in the factory

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Abstract—Feedback is to Human-Robot-Interaction (HRI) as Cinderella is to her bad stepmother and stepsisters. Feedback happens all the time between the involved parties e.g. robot-robot or human-robot, but receives little attention. Accordingly the important role and the need of feedback is undeniable. Our basic research concentrates on robots within industrial environments, in particular on Robot Programming by Demonstration (RPbD). We are surprised of the little notice feedback receives from researchers especially within the factory context. To get first insights we conducted a video-based focus group. With one video input for the functional and humanoid robot, respectively, we have evaluated people’s general expectations towards humanoid robots opposed to functional robots in a cleanroom scenario. The storyline of the scenario for both videos was a “pick and place” task, the most commonly considered task for industrial robot research. In this work we report qualitative results of the focus group with regards to feedback. This includes expectations of naive users concerning feedback in general. Furthermore we are interested in expectations regarding cooperation and feedback in a shared workspace which differs from current usage of robots in industrial environment. For RPbD, also known as Learning from Demonstration (LfD), we discuss feedback modalities to improve and support this alternative approach to robot control.

I. INTRODUCTION

Our research deals with Robot Programming by Demonstration within the factory context where industrial robots are in use. RPbD has to do with a human teacher and a robot learner and this may include interaction and cooperation. We use kinesthetic teaching for our research. That means people are in direct contact with the robot and share the same workspace. It follows that during the learning respectively demonstration phase feedback is very important to provide transparency and understandability of the robot’s internal state in order to increase efficiency and decrease errors.

Although our research focus lies within the factory context, due to safety regulations respectively restricted space in our laboratory and also limits of financial resources, we decided to use a humanoid robot as a research platform instead of a traditional industrial robot. One aim of our research is to investigate the users’ perception and assessment of the robots’ task execution after traditional programming vs. kinesthetic teaching. Therefore we conducted a focus group to find out general expectations towards humanoid robots opposed to functional robots in a cleanroom scenario. In this paper we will only pick out some of our results, namely feedback. To the best of our knowledge this is the first work providing a direct comparison between feedback modalities of humanoid and functional robots in a factory context.

In order to put our results into perspective, we give a brief review of RPbD and our definition of feedback. Thereafter we consider related work in the literature concerning feedback for functional robots and humanoid robots. Next we present our qualitative results of the focus group. In particular this means a direct comparison between feedback expectations towards the functional vs. humanoid robot in the cleanroom scenario and a discussion concerning overlapping work and alternative feedback modalities. At the end we focus on the question which feedback modalities are useful for the learning respectively demonstration phase of RPbD.

II. RELATED WORK

The approach of RPbD is not new and since years part of research in the field of robotics. In the year 1993 the first book dedicated to Programming by Demonstration (PbD) was introduced by Allen Cypher. In “Watch What I do” [1] he provides an overview about research conducted in this area, since the mid seventies. Soon, researchers recognized the potential of PbD as an alternative to the tedious manual programming of robots as well as cost reduction of the development and maintenance of robots in a factory. A fundamental survey of RPbD can be found in [2], [3], [4].

In robotics research, keywords like cooperation, assistance and social interaction attract people’s attention. All these keywords are part of HRI where feedback can be seen as one common denominator. The process of sending and receiving messages to achieve a certain goal is generally understood as communication [5]. During human-robot interaction we have to distinguish between two directions of communication. One goes from human to robot, the other is directed from robot to human. Based on the fact that feedback is used by any party in any direction, the term *feedback* for both directions is a little bit confusing. For the rest of our paper we divide feedback into two modalities. We speak about *input modalities* in case of human to robot communication. Moreover, in case of robot to human communication we refer to *feedback modalities*. Furthermore, the kind of meaningful input respectively feedback for a robot highly depends on its appearance.

Firstly, let’s have a look on functional robots in industrial environments which have been used successfully for decades. This machine-like robot is designed to fulfill a specific purpose like transportation and manipulation with a high speed and high accuracy during repeated movements in a known environment. Based on safety regulations from standardization organizations (e.g. [6]) which provide requirements for industrial robot manufactures, no shared workspace or

direct interaction with humans is desired. Rembold et al. [7] considered in 1994 a more flexible use of industrial robots. He suggested to extend the focus of research from fully autonomous robots to interacting and communicating service robots. Regarding input modalities much work has been done. For example Woern and Laengle presented a new intelligent robot control scheme for an industrial robot in 2000 [8]. Bannant et al. presented in 2009 [9] a novel approach how multimodal interaction between humans and industrial robots can be achieved. Literature on feedback modalities is missing for these types of robots.

The situation is different if we consider feedback modalities for anthropomorphic robots. The appearance is more human-like and from this we expect that we are able to communicate in a manner that supports the natural communication modalities of humans. Having a look on input modalities, Stiefelhagen et al. presented a system for spontaneous speech recognition, multimodal dialogue processing and visual perception of a user, which includes the recognition of pointing gestures as well as the recognition of a person's head orientation [10]. If we consider works regarding feedback a lot of effort has been done to make humanoid robots capable of generating meaningful feedback understandable to humans. Riek et al. [11] investigated in 2010 how people react to a robot making cooperative gestures. Salem et al. deal with the question how a robot's non-verbal behavior influences human evaluation of communication quality and the robot itself [12]. Liu et al. propose a model for generating head tilting and nodding [13]. Mirnig et al. use verbal and non-verbal feedback modalities for a humanoid robot to research the question how this feedback influences itinerary request in HRI [14].

To summarize, in the literature we find many different input and feedback modalities. Similar to the prince looking for the right girl that fits Cinderella's shoe, we struggle to find guidelines how to map the previous results onto our demonstration problem in the factory context. Hence, we research naive users' expectations towards humanoid vs. functional robots in the next section.

III. METHODOLOGY: FOCUS GROUP

We use a humanoid robot as a research platform. We use kinesthetic teaching for a "pick and place" task which implies cooperation in a *shared workspace* as opposed to *separated workspaces*, the prevailing situation in the factory. We have hardly any knowledge about expectations regarding feedback in the industrial context. Therefore we conducted a video-based focus group to research general expectations of naive users towards functional vs. humanoid robot in a production environment.

A. Scenario

The work scenario for both video inputs was the same. In the first video the functional robot and in the second video the anthropomorphic robot is used for a "pick and place" task within a factory. More specifically, a production equipment is being filled by one of the two robots with a wafer box.

B. Study setup and video stimuli

Two videos were shown as input to the participants of the focus group. The first video served as input for the functional robot, followed by discussion. The second video was prepared to show the Nao robot within a mock-up factory and served as the anthropomorphic input, also followed by discussion. At the end a questionnaire towards expectations was distributed to the participants. Both discussions were guided by interview questions.

This procedure was chosen based on the consideration that people better know the use of functional robots within the factory context than the use of humanoid robots. The effect was that participants transferred considerations from the functional to the humanoid robot as well as adapted them.

C. Research Question

The aim was to evaluate general expectations of naive users towards humanoid vs. functional robots within the factory context.

D. Participants

Eight people participated in the focus group (five female and three male). The average age of the group was 29.25 years (standard deviation (SD) = 8.10), ranging from 20 to 52 years. The majority of the recruited participants had only a private interest in technology. Two of them had pre-experiences with robots. A programmer and a psychologist gained experience within the scope of project work in the field of robotics. In RPbD non-experts should be able to teach/program a robot. Thus, we decided to recruit mainly non-experts (neither experience in programming nor production) for the focus group. It was important for our focus group to have some realistic inputs. To ensure a non-expert view on expectations with regards to anthropomorphic versus functional robots in the factory context it was relevant to have only a few members with pre-experiences within the group as they are the potential target audience of RPbD.

E. Interview Questions

The interview guide consisted of a total of ten discussion questions. Besides questions concerning safety, appearance, intelligence and autonomy, two questions dealt with feedback and cooperation as well as one with learning (see Table I).

IV. RESULTS AND DISCUSSION

This section is divided into three parts. Within the first part we present and discuss our findings regarding feedback of the focus group and compare the results between humanoid and functional robots. Due to the lack of work concerning feedback modalities for functional robots we will suggest imaginable alternative modalities for non-humanoid – more precisely – industrial robots. The remaining part of this section deals with feedback modalities in the context of learning focused on a "pick and place" task.

Although our scenario is focused on the factory context, our findings rarely differ from results of other works obtained

TABLE I
INTERVIEW QUESTIONS

Feedback	“What feedback do you expect from robots?” “How can a robot tell you, for example, that it has finished a task or is about to commence a new task?”
Cooperation	“How should the robot behave so that the work environment is pleasant? What behavior of the robot, would feel disturbing or hindering to you?”
Learning	“Imagine the robot is able to learn. You as an employee of the factory are assigned the task to teach the robot the same execution as shown in the video, namely refilling the production equipment. Teaching is done by demonstrating the execution of the task. Think how this can be best achieved without considering what is technically feasible.”

within another context. The participants suggested various traditional feedback modalities in mainly two categories: transparency and understandability of the robot’s internal state and error handling. Also here we can distinguish between input modalities and feedback modalities within the categories.

A. Feedback Types

In Table II we summarize the number of responses the focus group participants gave, grouped by feedback type. As can be seen the group was much more creative and more concerned with the functional robot.

TABLE II
NUMBER OF RESPONSES FROM PARTICIPANTS

Feedback type	Functional robot	Humanoid robot
verbal	2	5
acoustic	6	1
visual	10	6
haptic	1	0
general	12	10

B. Cooperation and Feedback

Concerning the transparency of the robots’ internal state it was important for the participants that the functional robot has a progress meter indicating the work step it is currently busy with. One utterance of a participant regarding the humanoid robot clearly explains the importance and shows in a direct way how feedback influences also other factors of interaction: “I cannot develop a feeling of trust so quickly, because I am not sure what the robot is doing next”. This progress meter should be provided mainly by visual feedback but also acoustic signals such as beeping are mentioned. The robot should either provide a message indicating the progress on a screen, or it should report its internal state via color codes. In this context J.T.C. Tan et al. investigated an information support system for human-robot collaborative cellular manufacturing system in [15]. In particular this means, that either the robot serves as an interface as a whole (e.g. by changing the surface color), or the robot should have at least big lights which can be readily seen from a distance.

To inform the user that a task is finished the focus group mentioned verbal feedback in the form of a confirmation message respectively visual feedback in form of a message on a screen. Concerning the humanoid robot the participants favor multi-modal feedback e.g. a combination of speech and a visual feedback on a screen. Their example was a monitor with a smiley on it when the assigned task is finished. Due to higher mobility the participants also suggested a laser pointer to know where the robot will go next. This desire is based on safety aspects. An interesting difference could be found regarding the general feedback nature: whereas the feedback of the functional robot should be unobtrusive, the participants would expect a humanoid robot to always inform the interaction partner what it is doing, so that the human stays always in control.

The second big topic considered by the group concerning feedback was the response to error conditions. The participants distinguished errors and anomalies concerning the robots’ internal state versus errors concerning the task execution and the environment. The last consequence when something unexpected happens, is the input modality to switch off the robot. The participants perceive both types of robots as a machine and request a switch off button for a feeling of safety. In [16] Bartneck et al. describe this behavior. The authors speculate that when robots will become more autonomous and intelligent, there will maybe someday be a conflict for the operator to switch off the robot. For both types of robots it is important that the robots provide hierarchical feedback. More precisely they should be able to distinguish between errors and warnings. The functional robot should display errors on a monitor in a classical way. The humanoid robot should be more autonomous and should communicate autonomously with the person in charge.

C. Learning and Feedback

Interesting results were identified in response to the question about the robots’ capability of learning. Within the field of “Learning from Demonstration (LfD)”, different approaches to build a demonstration dataset are defined: “Teleoperation”, “Shadowing”, “Sensors on Teacher”, “External Observation”. A comprehensive survey of robot LfD can be found in [3]. Surprisingly, all approaches were mentioned by the participants.

“Teleoperation” is an input modality and provides the most direct method for information transfer within demonstration learning. Next to kinesthetic teaching which is the main technique employed in our research, joysticking and speech dialogue also rank among this approach. The latter was discussed by the participants for both kinds of robots. However, for the humanoid robot more questions and comments were raised during the discussion. Besides the fact that the robot should be smart and capable of understanding the questions asked, it was important for the participants that the robot use feedback modalities such as verbal feedback in order to show the learning success. Not mentioned by the focus group, but introduced by A. Austomann and S. Yamada in [17] is the users’ feedback in a human-robot teaching task. The

interesting point in this work is the approach that the robot learns to understand during training phase the feedback given by the user. They suggested input modalities like speech and touch to give positive/negative feedback to the robot whereas gestures should mainly used for instruction and explanation. Participants also mentioned both robot should learn by observation.

In [3] two different approaches, namely “Shadowing” and “External Observation” are defined. Based on the embodiment, these approaches are easier to realize with the humanoid robot than with the functional robot. Often more than one sensor is combined for learning. For instance to teach grasping movements a force-sensing glove is combined with vision-based motion tracking [3].

“Sensors on Teacher” is the last approach we will discuss. This was also not addressed by the participants. However, the participants mentioned an emergency stop button somewhere attached to work clothes. This concept could be extended to provide further input modalities. For the humanoid robot the body movements of the teacher can be directly mapped whereas this teaching concept is more difficult for the humanoid robot.

The participants have not considered nonverbal feedback and input modalities such as gesture, eye gazing, etc. For humanoid robots there is a wealth of literature on such approaches. Interestingly, Y.F.O Mohammad and T. Nishida [18] suggested alternative (nonverbal) feedback modalities also for non-humanoid robots. We find this remarkable and a fruitful path of research. The participants mentioned before a laser pointer to know in which direction the robot will proceed next. An alternative approach for a humanoid robot is investigated in [14]. They proposed a pointing gesture to give feedback on navigation directions. Furthermore, it could be possible to take into account environmental and context information as an supplementary input modality. Within the group it was suggested the robot should adapt its speed of execution to the speed of the human.

V. CONCLUSIONS AND FUTURE WORK

Feedback is a broad topic. The aim of this work is to direct more attention towards feedback. Our contribution within this paper is the report of our focus group. We present a direct comparison of expectations regarding feedback between humanoid and industrial robots within the factory context. In particular we compare for both kinds of robots feedback types, feedback associated with cooperation as well as feedback in connection with learning. It is not a complete survey and related approaches still have to be considered in detail. In the fairy tale the prince invited the most beautiful women to the festival. Likewise we invite human robot feedback research to come forward. In particular that means to provide guidelines and surveys as well as a categorization that highlights differences between approaches, and to identify research areas within feedback that have not yet been explored. Our next contribution will be a user study in the field of RPBd were we implement

and explore proposed feedback modalities within the factory context.

The more guests invited to the festival, the higher the possibility that the prince will carefully select based on its requirements and find the most suitable feedback modalities. Can we fit Cinderella’s glass shoe and reach a happy end?

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