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Expression-rich communication through a squeezable device

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Abstract— **This paper presents Squeeze Me, a squeezable device used to grab attention from the mobile robot Care-O-bot, providing ground for expressive values to be shared between person and robot in a smart environment. Squeeze Me consists of a soft rubbery interactive cover, that can be mounted on a tablet, to enable expression-rich communication. The cover embeds two specifically designed resistive analogue pressure sensors.**

The expressions exerted on the device by the person are mapped to movements of the robot as well as to an expressive mask displayed on the graphical user interface (GUI) of the tablet that is used to control the robot. This mask shows the robot's view on the environment as well as its internal states (feelings). A short pinch exercised by the person on the cover results in a sturdy movement of the robot. A hard squeeze results in a quick movement and a gentle touch in a slow approach. All changes in movement are mapped to the modifications in the expressions of the mask, e.g. from neutral to surprise, or joy, depending on the context of interaction.

The paper describes the design and implementation of the Squeeze Me prototype, together with a scenario of use in the context of an older person – robot interaction.

I. INTRODUCTION

Tangible Interaction emerged in the 90s and rapidly evolved into a wide field of research with variegated application domains [1]. The approach emphasizes the design of the interaction beyond visual interface components [2], focusing of materiality, physical embodiment of data, bodily interaction and embeddedness in real spaces and contexts, as distinctive features [3].

In more recent years, through the acknowledgement of tangibility and technological developments such as multi-touch, 'natural interactions' have been pushed forward as seen in actions like pinching-to-zoom and turn-to-rotate. Nonetheless, interface designs have still large room to exploit opportunities of full embodiment of action in the environment.

In this paper we present an attempt to explore the possibilities for bodily interaction and contextual embeddedness through the development of a squeezable interface device. The device is a cover that can be mounted on a tablet to control different applications running on it.

Our research is inspired by the concept of embodiment as a way of theorizing the relationship between embodied actions, technology design, and our experience. This approach [4] provides a foundation for understanding how we are physically and socially engaged while acting in the world. Embodied interaction refers to the way our perception of physical and social phenomena develops in interplay with the world around us. Dourish defines embodied interaction as "the creation, manipulation and sharing of meaning through engaged interaction with artefacts" [4] (p. 126). Since its original definition, the concept of embodied interaction has inspired a number of design approaches considering "embodiment" as the bridge between the physical and digital. In particular this concept emphasizes the opportunities of action that the physical world offers and that should not be neglected in the design of digital interactive products.

For our approach to embodied interaction, we seek also inspiration in theoretical frameworks routed in basic principles of phenomenology [5] and ecological psychology [6] considering action and perception as situated in the world and not abstracted from it.

A context dependent, personalized action-possibility and expressive interaction is our concept derived from research on affordance and phenomenology, which put emphasis on subjective experience and context. Affordance refers to an action-possibility that is enabled by our bodies. This leads us to design for interaction, mapping the materiality and functioning to the action ability of people. Phenomenology stresses the unity between human beings and the environment, placing the body at the center of human existence, as a primary means of experiencing the world.

The uniqueness of life-world's perceptions, from a bodily and contextual experience is addressed in our work with the design of an embodied, expressive and context-depending interactive device [7]. In the specific application we developed, the device, called Squeeze Me, is connected to a GUI, and used to control Care-O-bot by an older person in a smart home environment [8]. This research has been developed in the context of the Accompany project (Acceptable robotiCs COMPanions for AgeiN g Years), that develops a number of functionalities of Care-O-bot to facilitate independent living of older people at home.

Care-O-bot is a state of the art service robot designed for home environments. In Accompany, the robotic system is specifically tailored to eldercare. The robot possesses different functionalities. The navigation system is based on an omnidirectional drives that allows the robot to move safely in populated environments. It has a 3-D environment

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detection via a variety of sensors that enables the robot to detect, identify and localize objects for manipulation with its 7-DOF-arm and 3 finger gripper. It is equipped with a tray that can be used to carry objects. It can fetch, carry, and manipulate objects. Other functionalities include monitoring of manipulation operations in real-time. Care-O-bot is part of an intelligent home environment providing information about the living patterns of the older person, current states of objects present in the environment (e.g., a dirty cup of coffee) and the environment itself [9].

II. SQUEEZE ME

The Squeeze Me device is an interactive cover, mounted on the tablet “Fig.1”, enabling expression-rich communication between a person and Care-O-bot [7].

Figure 1. Squeeze Me mounted on a tablet

By detecting the pressure on the cover, we directly map the values of the movement of the robot as well as the expressions on the GUI.

More in detail, the pressure exerted on the device by the person is mapped to expressive behaviors of the robot in the modality of motion in forthcoming interaction, as well as mapped to the appropriate expressions of the mask. A short pinch results in a sturdy movement, a hard squeeze results in a quick movement and a gentle touch in a slow approach. Each movement is mapped to the dynamic behavior of the mask. This direct mapping inherently exhibits a natural relationship while maintaining the richness exhibited by the user.

In the context of the Accompany project, Squeeze Me has been implemented to control Care-O-bot through a mobile GUI running on a tablet. In the following we describe the specific features of the GUI as well as a scenario of use.

A. The GUI

Following the theoretical frameworks illustrated above, the Squeeze Me device has been developed to be integrated with a GUI to control the robot.

Our GUI design explores the concept of context- and action-dependent interactions in smart environments. Actions to-be performed by the Care-O-bot are made available in order of their contextual relevance through the action-possibility-dependent and personalizing interface on a tablet.

The user is provided with two main modes of the interface. The first main mode provides action-possibilities to be performed by the Care-O-bot from the user's point of view (the user-view mode) while the second main mode provides them from the robot's point of view itself (robot-view mode).

The user-view mode is a view on which the user can see action-possibilities that are applicable to be performed by or with the Care-O-bot at the moment of interaction. The action-possibilities are organized by relevance; this is achieved through the size and location of the action-labels. The most relevant action possibilities are given centrally and larger than less relevant ones, making it easier accessible. In time, the user's usage of action-possibilities will influence the relevance as we target to provide a context as well as a personalizing graphical user-interface.

The robot-view mode provides similar action-possibilities that are relevant but does so from the point-of-view of the Care-O-bot itself. This means that while the Care-O-bot is not at the same location of the user, it provides a different set of actions to be performed. Their relevance is not ordered by location but merely indicated by the label size. The location of labels depends on the objects of action as this view displays the actual view from the Care-O-bots camera. So if an action-possibility concerns a dirty cup, lets say clean cup, the label will be displayed on top of this cup seen from the Care-O-bots perspective.

The GUI displays approach action-possibilities in the relation the Care-O-bot has towards objects in the environment. In fact, in the Care-O-bot's home environment objects have discrete, continuous and multiple-action-possibilities-per-object. A light-switch can be turned on or off, while a curtain can be opened fully, slightly and anything in between. A cup for coffee concerns multiple action-possibilities such as clean cup, fill cup with ..., bring cup to ..., refill cup etc.

The GUI provides different actions of selecting for each type of action-possibility “Fig. 2”.

Figure 2. Rendering of the GUI with action-possibilities in the robot-view mode

Thus action-possibilities are relations between actors and objects or environment. In this case the Care-O-bot towards objects and environment, therefore the graphical user-interface requires information about states of the objects to be handled by the Care-O-bot, about the states of the Care-O-bot himself, the environment as well as the states of the user and its unique approach to its world. In other words we require a larger picture of context. Lets say, an action-possibility ‘making coffee with sugar’ requires to know where the user is located (to bring the coffee to), whether the user is thirsty (not to provide coffee over and over again).

It further needs from the environment and objects involved whether there are empty and clean cups, as well as sufficient coffee, a clean coffee machine and so on.

The likelihood of an action-possibility is also defined by previous preferences and rituals between the robot and the elderly, that can hold in interaction in the long term.

We thus utilize desires and factual states of the actors (Care-O-bot and user) and physical states of the tangible objects and environment.

The through connection between action-possibilities and object states are conditions that have to be met in order for the action-possibility to be relevant. If someone just had a drink, and thereby has a low likelihood of thirstiness, the action-possibility ‘bring a drink’ is less relevant and should thereby be displayed smaller and more difficult to access than things that are relevant at the time of use.

B. *Expressive mask*

The robot-view displays what the Care-O-bot is looking at. This view is covered with a mask indicating a clear vision in the centre and dark blurred one outside the centre, as if looking through the eyes of the robot. The mask is designed to take the perspective of the robot and “share” its internal states. Other researchers have represented emotional states in robot using avatars (e.g. Valerie [10]). However, our intention was not only to represent internal states, but to actually take the perspective of the robot by looking at the external environment through its eyes. We believe that perspective taking favours empathic behaviour as discussed in [13].

The mask is dynamic. It shows different expressions “Fig. 3”, corresponding to internal states that are expressed via a shape-changing eyesight [11]. The mask is like a goggle view with an adjustable shape. The shape-changing eyesight is defined by several dynamic lines. The platform allows exploring dynamic expressions shown in the robot-view in relation to Ekman’s basic expressions and nuances found in the human face: neutral, anger, fear, disgust, joy, sadness, surprise [12].

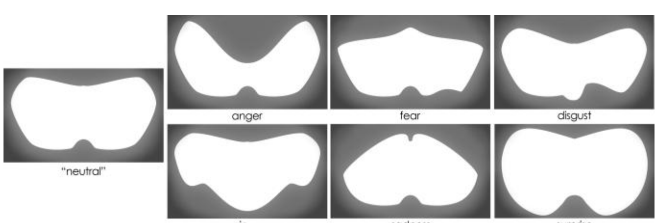

Figure 3. Expressions conveyed by the shape-changing eyesight: “neutral”, anger, fear, disgust, joy, sadness, surprise.

A comparative study has been performed to evaluate preferences of people in interacting with a static robot-view and with a dynamic, expressive robot-view (changing mask). The results showed a preference of people to interact with the dynamic expressive mask. Expressivity was a means to stimulate empathic concern and to facilitate perspective taking during the execution of the scenarios. Details of the study are described in [13].

Parameters taken as the internal feeling of the Care-O-bot are for example how full the battery is charged or the heat of the internal processor. Parameters taken as ‘feelings’ of the Care-O-bot, that are constituted within reciprocal interplay with the environment, are for example the temperature and light intensity in the space (either by how the Care-O-bot perceives directly by its own sensors or provided by external environmental sensors). Feelings directly induced by the elderly person in interaction are for example the expressive way the interface is handled or squeezed.

III. Scenario

In the following, we describe the functioning of the Squeeze Me device, in a narrative way taking the user perspective.

A. *Scenario “Bring me the coffee”*

Ann is sitting on the sofa right after lunch. She would like to have a coffee. She takes the tablet and looks at the displayed action possibilities. With no hesitation, she selects “Coffee” and adjusts her choice by adding sugar. Then she enters the command “Fig. 4 left”.

Care-O-bot comes into action and slowly moves to the kitchen to take the coffee. After a while, Ann checks what the robot is doing in the kitchen. The GUI on the tablet allows her to see through the robot's eyes.

Apparently the robot is taking quite a lot of time to complete the task. Coffee is ready. If the robot doesn't speed up, she will drink a cold coffee! Therefore Ann grabs the tablet with both hands and gently squeezes it “Fig. 4 right”. The mask displayed on the tablet turns from neutral to a surprised expression.

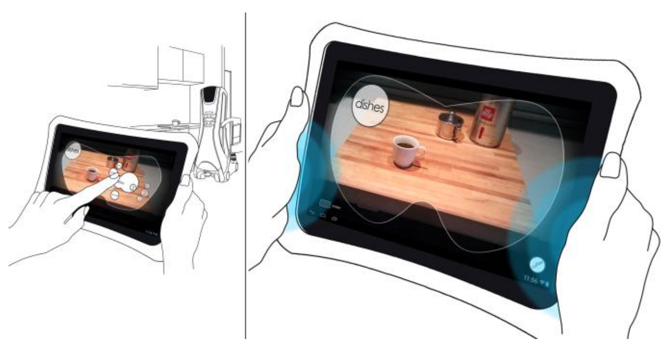

Figure 4. Ann selects “coffee with sugar” (left). Ann squeezes the tablet gently. The mask changes the expression from “neutral” to “surprise” (right).

The robot's behaviour changes too. Care-O-bot puts the cup on the tray and slowly moves towards Ann, not to pour the coffee. The irresistible smell of the coffee makes Ann impatient. She squeezes the tablet again, more firmly. The mask on the tablet turns to neutral and the robot moves more rapidly….but not rapidly enough for Ann…who keeps squeezing the tablet.

The mask changes from neutral “Fig. 5 left” to angry “Fig. 5 right”, and the robot slows down for a short while…..it is a bit moody…

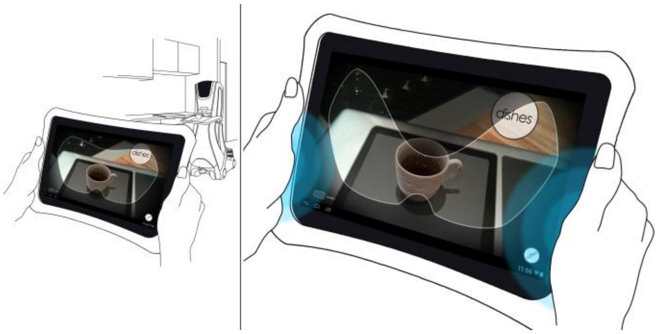

Figure 5. Ann looks through the robot’s eyes. She squeezes the tablet firmly. The mask changes the expression from “neutral” (left) to “angry” (right).

This is a little joke, a ritual among them. The mask turns again from angry to joy “Fig. 6”, and the robot rapidly delivers the coffee. Ann enjoys drinking and smiles to Care-O-bot.

Figure 6. The mask changes the expression from “angry” (left) to “joy” (right)

IV. IMPLEMENTATION

The following session contains details about the implementation of the Squeeze Me device.

The hardware is composed of three main parts “Fig. 7”:

- Cover
- Smart textile analog pressure sensors
- Electronic components

The software is organised in two main parts:

- Tablet software
- Cover software

By splitting the code, the cover becomes a standalone device, completely independent from the tablet. In this way, the technology is multipurpose, and can be integrated in different devices.

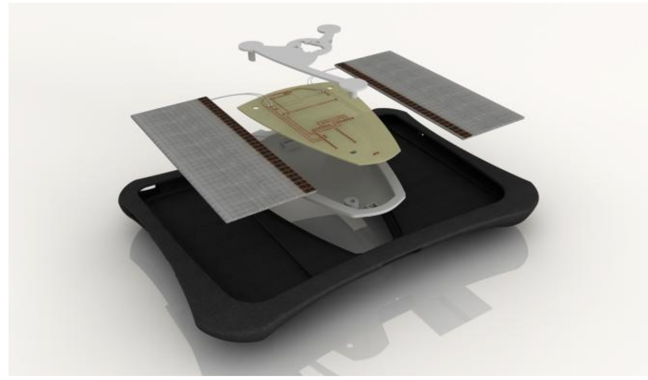

Figure 7. Rendering of the cover and the inner components.

A. Cover

The cover is designed to be ergonomic, comfortable to handle with one or two hands, and pleasant to touch and to manipulate “Fig. 8” It is made of a soft rubber that can be squeezed to share expressive behaviour with the robot, while the GUI displayed on the tablet allows for accessing actions to be performed by the robot.

Figure 8. Rendering of the internal part of the cover with sensors and electronics.

The cover is 3D printed using digital light processing technique (DLP), which uses a liquid polymer consolidated by the exposition to an adiactinic light. This technique allows the manipulation of soft-plastic materials. Moreover, the DLP printing allows for a high-level definition of the object’s details.

Two different plastic materials are used to print the cover. The black part is made of a dark malleable synthetic resin, whilst, the white part is made of an acrylonitrile-butadine-styrene (ABS). This harder plastic material allows to print a rigid central part of the cover which provides both protection and room for allocating the electronics. During the design process, we paid a particular attention to the modularity of all the cover's components. In this way, it was easier to assemble the components, as well as to fix potential malfunctioning of a single component.

B. Sensors

During the prototyping phase, we used simple and cheap force sensor resistors (FSR), in order to test the functionality and assess the positioning of the sensors with respect to the handgrip. After some initial testing, we replaced FSR with textile analog pressure sensors designed by Plug&Wear (http://www.plugandwear.com) "Fig. 9". These sensors work as an analog press button with resistive principle. It has a very high resistivity when not pressed. Its resistance decreases when pressed. (*http://www.plugandwear.com/datasheet/Datasheet_PW073_PW074.pdf*).

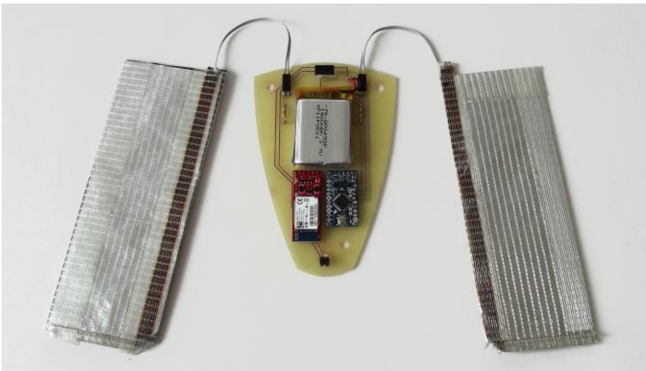

Figure 9. Smart textile analog pressure sensors and electronic components.

The smart textile pressure sensors have also the advantage to be flexible; therefore they allow to cover a wider area that becomes sensible to the user's pressure.

C. Electronic components

The inner electronics is the core of the system. It is composed of the following elements:

- Arduino mini 328 3.3v 8Mhz
- Bluetooth modem BlueSMIRF Silver
- LiPo battery 3.7 V 1400mAH
- Analog switch on/off
- 2x 10Kohm resistor
- Printed circuit board (PCB)

In order to reduce the encumbrance of the electric wires, all components are soldered on a PCB. The circuit diagrams are shown in "Fig. 10".

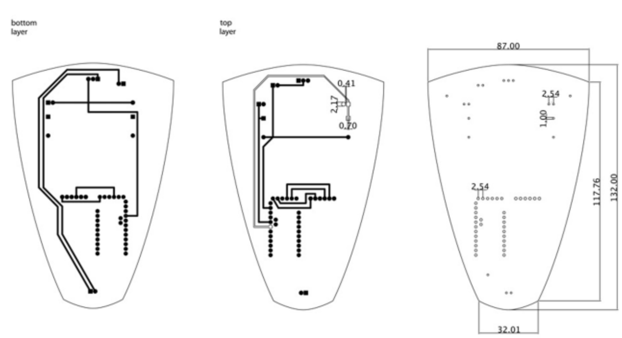

Figure 10. Circuit diagrams of the connections.

The circuit can be programmed via FTDI to a serial adapter. The power source of the system is a LiPo battery.

Both the cover and the internal circuit are designed to make it possible to recharge the battery through an external charger.

D. Software

The software controlling the cover consists of an Arduino sketch. It detects data through analog reads of sensor's resistance variation. By using 10 Kohm pull-down resistors (1 for each sensor), it is possible to obtain an interval between 0 and 1023. This range is divided in different intervals each one associated with a graphic transition of the mask. The pressure intensity applied to the sensors, allows variations within the interval, and therefore in mask expressions.

The code provides also a digital data smoothing; each sensor is read three times and the values are stored into an array from which the modal value is extracted. In this way, we can minimize measuring errors caused by noises.

Moreover, in order to avoid that the sensors are pressed inadvertently, the sketch is implemented in such a way that it is necessary to pass a minimum pressure value simultaneously on both sensors. This means that the cover has to be squeezed with both hands to be effective.

Below this value, the system remains inactive. After the detection and smoothing phases, data are sent to the Tablet via Bluetooth connection.

The software managing the expressive mask on the tablet is written in Java and has a twofold purpose:

- To realize the "morphing effect" among the various expressions of the mask.
- To control the robot's speed according to the pressure applied on the cover by the person when squeezing the device.

The tablet is connected to a database via WiFi, and with the cover via Bluetooth (serial communication). All the images related to the 9 basic expressions of the mask, are contained in an external database. All changes in expressions are realized through graphical transitions on the GUI. In order to achieve the "morphing effect", such effects, different images were designed, whose transition results in a pleasant and fluid experience. The software first checks if there are inputs from the sensors inside the cover; if no input is detected (nobody is squeezing the cover), the GUI returns a neutral expression and robot's movement results unmodified. On the contrary, when the person squeezes the device, the software retrieves the appropriate graphic transition, and the mask changes. The robot moves accordingly.

Concerning the robot's movement, the program detects data from sensors via Bluetooth. In particular, the electronics inside the cover filters the sensor data through the Arduino board, which returns a numeric value between 0 and 1023. This value represents the pressure applied by the person on the cover (0 is no pressure). The interval between 0 and 1023 is divided in sub-intervals, used to map both the value of the robot's speed to the sequence of images that realise the graphic transition.

The Squeeze me device has been implemented and integrated in the simulation environment of Care-O-bot "Fig. 11" to undergo some preliminary user testing.

Figure 11. The Squeeze Me device integrated in the Care-O-bot simulation environment.

The next step will be to integrate it in the real robotic platform and test it with elderly in a robot house used as one of the experimental sites of the Accompany project. Evaluations sessions have already been planned with an earlier version of the Squeeze Me, mounting a hard cover with a limited squeezable area. The early prototype was used as a proof of concept of the squeeze interaction mode. Ad hoc sessions with the latest version of the Squeeze Me, described in this paper, will be also executed in the next months.

V. Conclusions

With the design of the Squeeze Me and the GUI, we explored different opportunities for bodily interaction and contextual embeddedness in human-robot interaction. In particular, we developed a concept of tangible and embedded interaction that explores new forms of mapping of action and expression (intention), and new practices of sharing meaning between the person and the robot. These new forms of mapping are realised through different dynamics that make interaction subjective (likelihoods), rich (empathic and expressive interaction), continuous (mapping of input and output modalities in a continuous way), holistic and context depending (interaction driven by action-possibilities).

From the design viewpoint, the proposed solution is innovative since it relies on mapping actions and their effects through a continuous action-perception loop exploiting the richness and continuity of our human embodied skills.

From a technological viewpoint, the Squeeze Me addresses a number of challenges. First of all, the exploration of smart textile sensors combined with soft plastic materials. The choice of the material is fundamental to afford squeezing, and to provide a pleasurable experience of touching and manipulating. The choice of form and material is fundamental to afford squeezing, and to provide a pleasurable experience of touching and manipulating, together with a functional way to mount and dismiss it.

It is also worth mentioning that the adopted implementation allows the cover to work as a standalone device, completely independent from the tablet. This opens a wide range of possibilities for new applications of the device, from gaming to video-shooting application. More in general, it is suitable in contexts where expressivity in action can play a relevant role in what we are trying to achieve.

Acknowledgment

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