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Human Action and Experience as Basis for the Design and Study of Robotic Artefacts

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***Abstract*— This paper aims to illustrate how robotic artefacts and applications may be described from a perspective of human action and experience. This is done by presenting an interaction model based on four ways that interactive artefacts may work as *resources* for human action. In contrast to data-centric models, this model includes socially and contextually oriented actions performed around the artefact, as well as actions related to the computational system running on the machine. A goal with the framework is to provide a concrete reference for designers, focusing on the experiential dimensions of the products that they develop.**

I. Introduction

INTERACTION with robotic technologies raises a number of parallels to some of the themes that have become increasingly discussed in Human-Computer Interaction (HCI) in recent years, including aspects of aesthetics, affective interaction, embodied action, mobility, and situated aspects of human activity. Central to this is an increased emphasis on how to empathically address the *experiences* of those who will encounter the technology [5, 13]. The increased commercialisation of robotic products is also related to the recent acknowledgement of systems development as a *design-oriented* field of study [6], using e.g. methods from industrial design to complement approaches grounded in engineering and psychology.

In order to further understand what is meant by an action and experience-centred perspective in the area of human-robot interaction, this paper presents an interaction model based on a perspective of *technology as resources for human action* [4]. The model was initially designed for the domain of Tangible Interaction, a technologically related field to robotics that deals with systems that use an increased range of physical objects for manipulating and controlling computational systems. Much of the conceptualisations in that area [e.g. 23], could be directly applied to robotic applications, for instance how the embeddedness of hardware and sensors make interaction with these technologies difficult to fit into standard information processing paradigms. The different parts of a robot may for instance simultaneously be recognised as input- and output devices, as well as representations of 'data'. The mere physical manifestation of robots and robot action is thus a major motivation for seeking out new ways of describing action and interaction within the field of Human-Robot Interaction (HRI).

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The model makes explicit four different ways that a physical interactive artefact may work as resources for human action and experience, i.e. for:

1. Physical manipulation
2. Perception and sensory experience,
3. Contextually oriented action, and
4. Digitally mediated action

Like most frameworks that seek to address user experience in the development of interactive systems, these four dimensions are philosophically grounded on a phenomenological perspective on user action, as well as on aspects often put forward within the so called 'practice turn' of the social sciences [see e.g.17, 18, 20].

To illustrate how this model can be applied, brief examples of commonly observed interactions with robotic artefacts are presented. The paper ends with a short discussion on how models such as these may be used in design and evaluation to capture interaction qualities of robotic artefacts that may otherwise be easily overlooked.

II. An Action-Centric Perspective of Interaction

Within the paradigm of desktop computing, a standard way of conceptualising interaction with technology has been through notions of information processing, where *the computer system* is the main point of reference. Such a perspective focuses on how data or signals are inserted to the system via various input devices, then processed, and finally returned to the user via some form of output device. The world outside of the device is sometimes modelled as a computational representation used by the system to predict and interpret user actions. This perspective is here referred to as a *data-centric* view on human-technology interaction.

What is usually missing in data-centric interaction models is that they not explicitly address aspects related to the physical and social context of the activity. Nor do they acknowledge sensory or experiential aspects of interacting with a system. It is therefore relevant to explore models that more naturally include these dimensions – especially as much of the argumentation for, as well as empirical studies of new interactive technology (including robots) are emphasising exactly those aspects.

Moreover, as robots are often designed to act autonomously, and given the psychologically-driven character of many of the research questions explored in the field of HRI, it may be difficult to grasp what exactly this should imply for the development and study of robotic artefacts. For instance, as a researcher in this domain, it may be difficult to identify who's "expectations", "predictions" or "goals" that one is referring to (those of the robot, or those of surrounding people?).

A related challenge for designers concerns how to manage that users often encounter new robotic systems with unrealistic expectations from popular media and fiction. This means that varying physical forms, as well as the cultural notions of what a 'robot' is, makes this an area that is essentially different from the design of software running on more conventional hardware platforms. Moreover, as robotic systems generally require more resources than other computer systems to manufacture and deploy, a further challenge concerns how to perform studies of how they are taken up, maintained and used in realistic settings.

Rodney Brooks [1] is one of the most well known critics of the data-centric stand on designing robotic systems. Brooks has primarily criticised the heavy use of representations in AI systems, and describes how actions interpreted by people as equally intelligent could be achieved without having to model the world internally as a computational representation. Brooks proposed that a more efficient way could be to use the world itself as an always up-to-date and accurate 'model' and use emergent behaviour of simple rules as base for autonomous robot action. This also emphasises the general relevance of looking upon computer reasoning from a perspective of physical embodiment rather than only from a perspective of data manipulation [15]. Similarly is Alex Taylor's elaboration on the concept of 'machine intelligence' [22], as potentially grounded in the design of e.g. response mechanisms of digital artefacts, and how these actions are perceived and interpreted by people.

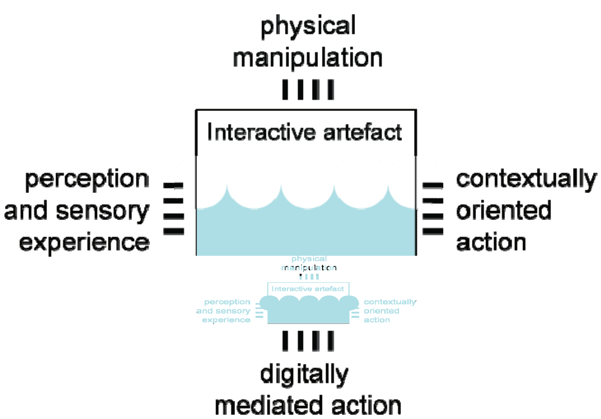

Figure 1. An action-centric model of interaction, pointing at four different ways that a tangible object may work as a resource for human action, as presented in [4].

Several scholars have recently brought to discussion different ways of framing how an *action-centric* perspective on interactive technologies could take form. Klemmer et al [12] for instance, discuss this in terms of bodily action, and point to a range of new challenges that this may bring to designers of digital products. The recent framework of Reality-Based Interaction [10] also emphasises a number of aspects related to bodily practices and skills as central considerations in the design of 'post-wimp' user interfaces. Similarly, Dourish [3] and Hornecker and Buur [9], ground their views on physical interfaces on the idea of interactive systems as resources for shared human sense-making.

Within HCI, this broad collection of themes is sometimes referred to as 'third wave HCI' [2, 8]. Importantly, third wave HCI is not merely a question of letting the intended users have a say in the design process, or to investigate their expectations, desires and performances, but to look upon the interaction more fundamentally from a perspective of what people actually *do* with the technology. As an attempt to address these concerns, and to provide a concrete alternative to data-centric models, the framework presented here is based on the concept of technology as *resources for human action* (Figure 1). The model was designed to make explicit a number of use qualities of tangible systems that are difficult to capture using data-centric models of interaction.

The model shows four different types of action that are afforded by tangible interactive objects: 1) physical manipulation, 2) perception and sensory experiences, 3) contextually oriented action, and 4) digitally mediated action. Each dimension may support a range of different actions, which in the model is illustrated by several short lines. Visually, the model borrows the metaphor of the digital and physical as divided by a water surface, as introduced by Ullmer and Ishii [23], although this separation here is more subtly conceptualised as embedded within the artefact. Another main difference is that this model focuses on *human action and experience*, rather than on the flow and representation of information.

It should also be noted that it is often difficult to make sharp distinctions between the four modes of actions, as most interactive settings include a combination of all of these together. Table 1 shows a set of initial questions derived from the four dimensions. The questions are intentionally broad and open-ended, so that designers, engineers as well as analysis could use these to identify and discuss relevant aspects in relation to the particular system and use setting that they are working with.

III. Robots as resources for human action

Below is an attempt to illustrate what is meant by the four dimensions of robotic artefacts as resources for human actions, as outlined in Figure 1. Several examples from commonly observed human-robot interactions are provided, as a way of showing how the model and the set of questions could be used as reflective resources in the design as well as in evaluation of robotic systems.

A. Physical manipulation

This dimension concerns how physical objects may be moved and interacted with in space, how they may be physically combined, be brought to different environments, how they allow for action and interaction to be performed concurrently, with both hands, jointly or individually. It seems that from a perspective of human experience, it is sometimes difficult or even irrelevant to distinguish the physical manipulations that are treated computationally by the system, from those that are not. An example is how users of a mobile robot may get it to move in another direction by obstructing its path, by physically pushing it, or even carrying it to a new location. From a perspective of use, it may be unknown how these actions are treated computationally or mechanically inside the robot. Therefore *all* physical manipulations that people may and do perform with the physical object are collected in this category.

All this is closely related to the concept of *affordance* from perceptual psychology, referring to the perceived quality of an object in terms of how it allows an individual to perform an action. A certain kind of robot movement may for instance work to 'invite' the user to touch or gesture in a certain way. Similarly the physical materiality may trigger certain manipulations. A robot with a hard plastic cover may for instance be perceived of as more 'bathable' than one covered in a soft fabric, even though the technology in both cases may be similarly sensitive to water. Similarly a robot may be perceived of as 'carryable', 'huggable', 'not touchable', etc.

Our first question for this dimension asks designers to identify the *possible (and likely) physical manipulations to be performed on the device*. This ranges from completely physical considerations of how the robot may or may not fit under a table or through a doorway, how its wheels can get stuck on uneven floor surfaces, and how its loose parts may get lost, stolen, hidden, etc. Another example may be how it is possible to put clothes and other physical markings on the robot, and how these may fit or be attached on the robot surface (e.g. the practices of creating decorative covers for household robots, often with the purpose of making them more decorative when *not* in use). When it comes to studies performed in real world settings such aspects may be central to what users are observed to do as well as what they comment about. Rather than having to treat such observations as anecdotal comments or unexpected add-ons to the user studies, this model includes them as expected and essential already in the design.

Naturally, physical manipulation with interactive technology also includes several digital aspects, e.g. the importance of physical nearness when using Bluetooth or RFID, directing the robot to respond to IR signals, and pressing of hardware buttons to control the system running on the device. Importantly, physical manipulation also includes several aspects of concrete physical management, such as procedures of changing or charging batteries, switching the robot on and off, how it can be cleaned and groomed, and how the robot may be physically moved and stored. As with any process of product development, all these aspects must be actively designed for as well as taken into account when evaluating a new robotic artefact. However, in most models used for describing the design of interactive systems, offline physical interaction is omitted.

Our second question for this dimension asks analysts to pay attention to *how users are observed to actually handle or manipulate the device*. Again, it may be noted that many of the physical manipulation that users perform with a robot are off-line, i.e. not sensed by the digital system, yet of relevance for people interacting with it.

B. Perception and sensory experience

This dimension concerns personal, bodily and emotional engagement with technology, e.g. how a robot feels like to

Type of resource	Questions in the design	Questions when studying interaction
For physical manipulation	What physical manipulations *can* be performed on the device?	How *do* people physically handle or manipulate the device? ("offline" as well as "online" actions)
For perception and sensory experience	What are the perceivable features of the device? (digital as well as physical)	What *senses* do users direct to the device? What *emotions and interpretations* do they express?
For contextually oriented action	How is the design meant to support an existing context of use?	How do people act *around* the system? How do they make it part of their existing practices?
For digitally mediated actions	How is the *software* designed to respond to or mediate user action?	How do people use the system to control, act, and communicate digitally?

Table 1. An initial set of questions to be used concretely in design and in evaluation, based on the four different ways that an interactive physical object may work as a resource for human action.

hold, touch, to look at and to listen to. Affective experiences such as fear, curiosity and attachment, which are becoming increasingly important aspects of HRI investigations, are also included in this dimension. Related to perception and sensory experience is also concepts of skill and body memory, as discussed as important features that are often neglected in the design of new interactive systems [12]. A concrete example is how an experienced user may control a robot by moving the physical parts of a controller without having to actually look at the device.

As a first initial question for this dimension we are asked to identify the *perceivable features of the device*. Importantly, perception and experience is not primarily a question of what is displayed and presented, but more importantly how the artefact as a whole is perceived and made sense of. This not only includes device-specific qualities of the hardware, e.g. to feel weight, texture, hotness, etc, but also of digital expressions, such as the experience of sound and visuals on a screen. Noise of a fan or motor movement may then be just as relevant as designed computational audio that the device emits through loud speakers. For robotic devices, this also includes physical motor actions that the object performs, and how these are perceived. A particular perceptual quality of physical robots is also how their dimensionality in space makes them viewable from different angles, allowing for several people to get an individual viewpoint of the robot.

As a second set of questions we are asked to identify what *senses* that users seem to direct to the device and what *emotions* and *interpretations* that they express. For instance, if the robot has something that 'looks like' eyes, users may get the *experience* of being watched, even though the robot in fact does not record anything. The eye-contact seeking iC Hexapod robot (by Micromagic Systems) could be used as an example for this, as it is very convincing in this respect. A related question that is sometimes brought up in user studies is also whether researchers (or companies) may be able to spy on the participants *through* the robot somehow. That is a rational concern, given the capabilities of commonly available technology (TV, radio, telephones). An implication of this is that issues such as privacy and data security may be relevant to discuss not only in terms of what the system is *actually* doing, but also in what people *experience it as capable of*.

An action- and experience-centred perspective requires analysts to identify the features of the interactive setting that people actually pay attention to, and if possible also what interpretations they make of these. Importantly, perception and experience are here understood as actions *performed by people*, rather than passively imposed from the artefact. The physical outside, buttons, surface markings, etc, then not only present available functions but also more subtle keys for interpretations, not always possible to foresee in the design. Someone may have made the robot more personal by placing stickers on it, its surface may have got shaped by wear and tear, and a particular person may perceive and interpret such signs in a variety of ways. All such interpretations are considered as active engagements by people, based on their personal experiences and expectations.

C. *Contextually oriented action*

For any technology to be used by people, it is relevant to consider how it could be taken up and used as a resource in existing socio-technical contexts. As designers, we need to ask ourselves what situations the technology is meant to support, who would benefit from it, what existing practices they would be engaged in when using it, and what kinds of technology they currently use in these practices. For a robot targeted at children, it may for instance be relevant to explore how it may fit or function together with other physical toys and how it may be incorporated into ongoing play activities. Other aspects may include who will be responsible for charging or changing batteries, what will be the required skills for updating software, or how the product conforms to established guidelines for health and safety, cultural norms, sustainability, etc. Moreover, we may need to understand how it could be used for co-located social interaction, for remote communication, and how it may work with other tools in an existing social practice.

As any physical object, a robot may be used as a resource for getting attention by others, as an indicator of the current state of an activity, or as a trigger for new conversations. A concrete example is how owners of the commercial toy dinosaur Pleo reported how they placed the robot in their office reception as a form of 'ice breaker' with their customers [11]. A more subtle example is how a remotely controlled Kaspar robot was observed to work as a social mediator between puppeteer and child [16]. Other contextually oriented actions include moving other physical objects in order to clear the path of a robot, and how this sometimes becomes an essential part of acting around it, even if it may not be considered as interaction *with* the device as such. This class of action thereby includes all of the actions that people perform that are not directly directed towards the system or artefact, but that yet seems important for how users interact with or around it.

When studying a system in use, this dimension asks us to study not only the direct interaction *with* the device, but also how people interact more generally *around* it. For instance, gesture and physical manipulations upon the device may in fact be directed to the social context, e.g. in the form of handing over a handheld robot to a friend, pointing to draw attention to a certain feature of the technology, or teaching another person how to use the system. Of particular importance then are aspects such as intended and unintended *audiences* of the interaction. For instance both sound and gestures are multidirectional forms of media and may reach the surrounding context as much as it will reach the intended target. Therefore speech, sound and gestures generated by the user as part of the interaction could always be considered as at least partly contextually oriented, even if it may be intended only towards the robot.

Another form of contextually oriented action, which has been brought up primarily in the domain of games and play, is the notion of *performed belief* [14]. Performed belief occurs when people pretend that they believe something, for instance when participating in a game, or to make an otherwise unnatural activity meaningful. Playing along with the idea of a robotic artefact being a 'live creature' is one possible example of such behaviour, and which seems especially common around robotic artefacts, even with very simple appliances [21]. A related aspect is how people sometimes appear to speak to technical artefacts, even if they are well aware that the technology as such does not respond to speech. These actions are here defined as contextually oriented, as the primary targets of the interaction do not seem to be the robotic artefacts *per se*, but the context around them.

D. Digitally mediated actions

This class of action concerns how the technology supports users in controlling and performing with a computational system. This includes the design of all forms of applications made accessible through the device, and how different forms of media can be captured, generated, communicated, controlled and manipulated. As resources for digitally mediated actions, robotic devices may provide new possibilities and precision in manipulation and navigation in virtual spaces, richer ways of accessing recorded and interactive media, or for remote communication between people. Other examples include how physical buttons, speech, or gesture recognition software may work as direct controls to actions that a robot performs. Typical examples are the ones used for explorations of inaccessible or dangerous areas (e.g. the planet Mars explorations [24]), or for controlling or recording data from a robot via any form of external equipment [e.g. 7].

This dimension also includes actions where the robot performs autonomously, e.g., an industrial robot that with great precision assists a worker by repeatedly perform a complex manoeuvre, a robotic toy that can be trained to perform new actions, or robots designed to entertain and amaze by performing on stage (e.g. a Rubic's Cube solving robot). Note however that actions performed autonomously by the robot but are left unnoticed by people, are here treated as irrelevant. A possibly disturbing aspect of this is that it may be seen to neglect relevant discussions of 'robot perception' or motivations for 'its own' activity. Many robots do for instance perform their actions based on actions in the environment that are not initiated by people, e.g. animal-robot interactions, robot-robot interactions, as well as issues related to autonomous maintenance. However, some of these actions may in fact still be relevant and interesting for users, and thus still be regarded as resources. For instance, a medical robot that acts upon actions performed unconsciously by a patient (e.g. change in body temperature), or one that autonomously recharge its own batteries, may be fundamental to the user experience.

Importantly, from an action- and experience-centred perspective, the software of a robot is described in terms of tools and resources, asking designers to address the *interactive* features of the technology, i.e. how actions that users perform are taken up and mediated by the device (rather than the other way around). This includes considerations of what users do to control, program, update, and communicate digitally through the robot, and how the robot succeeds in responding to those expectations.

Digitally mediated action is fundamental to all HRI, and is also the aspect generally focused on in traditional data-centric models of user interaction with technology. However, this does not imply that digitally mediated action should be regarded as 'data manipulation' only. Especially in robotic systems, the interaction often seem to contain almost as much meaning in the physical space as is displayed as digital data output. An example can be how the therapeutic robotic seal Paro [19] responds to touch as a form of direct and continuous movement, in a way that is difficult to capture only through a straightforward diagram of explicit 'input' and 'output'. Defining the 'data' in physical interfaces is also generally difficult as it is not always clear what a device is actually recording.

IV. Discussion

The interaction model presented here is intended to provide an overview of how robotic artefacts may be described when studied from a perspective of human action and experience. The four dimensions make explicit several aspects that are commonly set aside when using a data-centric perspective of analysis, e.g. that physicality, maintenance, as well as social and technical contexts are essential properties of human-robot interaction.

Moreover, what is made explicit in the model is that the software of a robotic device in a very concrete sense is founded on its physical hardware, emphasising the physical and digital as holding equally intrinsic qualities in the interactive setting. Rather than bridging a gap between physical and digital – being an *interface* – the important qualities are here regarded as embedded in the interaction, where physical and digital, social and experiential must be designed and studied together. Naturally, essentially all software must be tailored to some specific form of hardware, and interactive applications always rely on the interplay of tangible and digital artefacts and materials. However, this seems to become especially evident for the design of robotic and tangible systems.

At the current stage the model is intended primarily as a guide for directing oneself towards the system from a perspective of people, rather than from the (within HRI more dominant) perspective of system functionality. In contemporary HCI research, this could be seen as the mainstream attitude when performing user studies as well as when arguing for new designs. However, to this date surprisingly little research in HRI seems to actively address these kinds of aspects. Even though the model does not provide any specific criteria in terms of use qualities to strive for in a design, we hope that it may open up for a broadened discussion on use qualities within HRI, as well as in more concrete design projects.

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