The Material Move
How Materials Matter in Interaction Design Research

Ylva Fernaeus
Dept of Media Technology and Interaction Design
Royal Institute of Technology, KTH
Stockholm, Sweden
fernaeus@kth.se

Petra Sundström[i]
ICT&S Center, University of Salzburg,
Salzburg, Austria
petra.sundstroem@sbg.ac.at
(projects conducted while at Mobile Life)

ABSTRACT
The topic o*f Materials* has recently surfaced as a major theme within the research field of interaction design. In this paper we further discuss the need for in-depth descriptions of specific design cases, by revisiting some of our own research-through-design efforts when working with new or not yet fully explored materials for mobile interaction. We outline a series of design challenges that we see commonly arising in this domain, divided into three general themes; 1) affordances of hardware and casings, 2) experiential properties of different software solution, and 3) material properties of sensors, radio-signals, and electricity. Our main conclusion is that research in interaction design needs an extended focus on how systems are crafted from and together with properties of digital materials, and how new knowledge gained from those processes can be shared.

Author Keywords
Design, Materials, Mobile technologies, Movement-based interaction, and Interdisciplinary design.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design

INTRODUCTION
It has been repeatedly argued in the methodologies of interaction design that creating a fully working interactive system is not merely a matter of 'translating' a static sketch into its dynamic gestalt [e.g. 22]. Therefore a general focus in this area has been to develop alternative ways of visualizing the dynamic properties of intended systems in the forms of for instance videos, role-plays, scenarios, and flow diagrams [see e.g. 20]. Yet, the path from such forms of sketches into actual implementations often involves a range of design choices beyond what is possible to capture in any of these manifestations.

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Since it is so difficult to start over once you have started to actually build something, classic interaction design methodology encourages us to first get a sense of the use context aimed for, to set up a clear overview of the conceptual design, develop concrete use case scenarios, testing of interface features through low fidelity mockups, and thereafter work iteratively with high-fidelity prototypes. This methodology was largely developed for desktop computing, with its underlying assumption that the designers, as well as the end users, would know more or less the limits of the technology at hand. When working with novel technical setups, e.g. with new sensors, platforms or technical protocols that none in the development team has yet had a chance to work with before, such methodologies need to be revisited. In many cases, it might be that we work so long on the more conceptual parts of a design that we end up fighting the materials to fit with the conceptual idea – instead of allowing material properties to guide our design. Also, the ways we combine the technical materials with each other have effect on what properties they will get and how they play out in a specific design situation.

We see a danger that HCI practitioners sometimes trivialize the role of technological choices required to actually cater for a good user centered design, and that a design that does not end up working well gets excused by being a mere technical mishap or bug that could be solved if only the engineer who implemented it had been more skilled at *his/her* practice (i.e. and that *that* practice is not something that the designer or HCI practitioner should have to worry about). What we need instead, especially when working with new forms of interactive materials, is to devise ways of bringing the materials into the explorations earlier in the design process, and also make them a shared resource for everyone involved, e.g. designers, developers, engineers, HCI-experts, dancers, psychologists and end users. Also, the materials will continue to have an effect on the design idea at hand and that throughout the whole development process. A design team needs to continue to work together and discuss the idea from the situation at hand for a longer period of time than the initial phases of a design process.

The above situation, together with theoretical frameworks and understandings predominantly from within the areas of tangible, ubiquitous and embedded systems design, have most likely contributed to the emergence of what one may now refer to as a *material move* within the field of HCI. Dourish and Mazmanian in their recent paper *Media as Material* [4] as well as Blanchette in *Material History of Bits* [2], both discuss the physicality of digital matters, as an inherent and fundamental part of computation. Several design researchers such as Hallnäs and Redström [11], Vallgårda and colleagues [e.g. 30] and Sundström and colleagues [e.g. 29] have been addressing the digital from the perspective of being the design material within interaction design.

Compared to the traditional view of HCI, the material move makes HCI more aligned with central concepts in design, such as what Schön refers to as a *conversation with materials* [25]. This perspective is also supported by the recent development of various construction kits and open hardware platforms, such as Phidgets[1] and Arduino[2], which let amateur hardware developers, makers and designers from disciplines not normally involved with interactive technology, handle more physical properties of the digital materials. However, this conversation with materials is not only about collecting knowledge of digital materials in a similar form as e.g. IDEO's tech box[3] collection of physical materials, it is about understanding the practice of working with the digital materials, how they will play out in design and how to work with them from the perspective of interdisciplinary research through design. It is not until a system is set together that we completely can come to understand how the materials we are working with will work together and play out in that specific design. And it is not until then that the interactive properties of the design completely can be decided upon.

From this perspective, there is a need for richer descriptions of how and when materials matter in interaction design processes, both when we make prototypes in academic research-through-design settings, as well as in real commercial end-product engineering.

In this paper, we bring to discussion a series of design challenges that appear to commonly surface in the design space for *tangible devices, movement-based interaction* and *mobile technologies*. We illustrate these challenges with examples from our own past design practices in research contexts, exemplifying how we have worked with materials and how we in our design teams have tried to shape solutions based on available material resources. We also discuss how the designs had to take form before we completely comprehended the materials worked with, and what they could do for that specific design.

[1] www.phidgets.com
[2] www.arduino.cc
[3] www.ideo.com/work/tech-box/

BACKGROUND

Interaction designs that take advantage of and make extended use of physical and bodily action is an exciting and growing area of research in interaction design. Research topics in this field include systems that make use of hand gestures [e.g. 23], peoples' movement through space [e.g. 3], dance [e.g. 6, 12], and the design of hand-held, tangible artifacts [26]. Compared to conventional PC or laptop-based interactive settings, the making of such systems often requires new elements in the design practices. Jonsson and colleagues [16] for instance, explored this topic from of how system developers orient themselves in their practices when building systems for unconventional hardware platforms, and how that affects e.g. the activity of programming to get more integrated with iterative testing.

Interaction technologies used form making mobile and movement based systems include computer vision-based setups, accelerometers, various kinds of tagged objects and readers (e.g. NFC/RFID), location based protocols such as GPS and triangulation with radio sensors nodes, motor-driven devices and sensors tracing light and audio. Until recently, all these technologies were explored as special cases outside of what was commonly perceived as mainstream interaction design, e.g. in more technology-oriented subfields of HCI such as ubiquitous computing. However, with the recent development of accessible and sensor-rich mobile platforms, it is no longer unusual that researchers in more conventional design projects make use of more elaborate sensor solutions as parts of their designs. Yet, and as already stated above, designers of such systems are faced with a number of challenges, stemming from limited shared understandings about how exactly different technologies work, and thereby difficulties with adapting their designs along with the materials they work with.

This brings us to what we in this paper refer to as 'materials'. By the term 'digital materials' we here and previously [see e.g. 29] refer to technology that can sustain an interaction over time with users (creating for a dynamic gestalt [19]); thus it includes both hardware and software, and is manifested in hardware platforms such as mobile phones or laptops, but also in the different parts they are made from, such as sensors, network communication, radio or touch screens, as well as programming languages and operating systems. We have chosen to use the broader term 'materials' to describe the 'material knowledge' required by interaction designers, although a more adequate term may be what Vallgårda and Redström talk of as *computational composites* – alloys made up of a combination of electronics, software and more traditional materials that all of them together impose particular properties [30]. Very rarely, if at all, do we work with technologies in their basic form of zeros and ones and various voltage levels. In this paper we explore this broad field with a general focus on handheld devices such as mobile phones, but also other interactive artifacts that afford movement and mobility.

From an interaction design perspective, a central challenge is often to make appropriate use of the experiential qualities of the design materials available, and to artfully incorporate those into an engaging interaction that embodies some aimed for sensations. Mobile systems are in this respect interesting both since they often rely on rapidly changing and evolving materials, and that they may be more sensitive to environmental factors. Especially movement-based systems are sensitive to finding e.g. the right timing and rhythm of interaction where there can be no break-ups or delays. Mobile and movement-based systems is therefore one area where a closer look at materials and details of implementation is needed. We also see this domain particularly interesting for the point we aim to make with this paper: that material understandings matter fundamentally in user-centered design processes, and we need ways for thoroughly discussing, sharing and documenting this knowledge within the research community.

The relevance of working closely with materials is well known in the fields of design as well as in engineering [e.g. 21]. It is also a core element of knowledge for most interaction design practitioners, who often specialize to be experts on a particular interaction platform. However, in the academic field of HCI, this dimension has lately been argued to be overlooked in relation to user experience and usability [by e.g. 14, and 29]. We see several reasons for what may have caused this underestimation of material knowledge in the domain of interactive systems design. One reason could be the complexity of *the digital* in how it unfolds over time and space [11], which makes it hard to show, share and fully understand, and that it often takes some time to get a design to the level where it can be showed and shared. Another reason may be because we have been taught that 'the digital' is a plastic material in which we can build almost anything [20] and therefore a material we do not have to consider in the formation of new ideas. A third explanation could be that material properties have been more salient in he context of desktop computing. Our final suggestion, which we find especially intriguing, is that many of the 'materials' worked with in this field are themselves changing over time, making designers uncertain of their value in terms of lasting knowledge. We believe, on the contrary, that the changing nature of our design materials calls for an increased need of documenting the learning processes around the materials we have at hand.

If we believe we work with a material with which more or less anything can be realized, it is of course natural to focus more on the conceptual aspects and consider the core effort in the design process to lay in the production of visualizations of the intended ideas in the form of video, scenarios, and the like. But when the interactions we envision involves new interactive resources and materials and thereby is not under the full control of designers, such processes run the risk of resulting in what Holmquist refers to as Cargo Cult designs [13], i.e. designs that do not take into consideration how the resulting product should actually be possible to realize. Actual functionality cannot be expected to rely on concepts and sketches only, and there is no coincidence that the more successful interaction designs are built on deep technical understandings of the specific materials worked with (together, of course, with appropriate understandings of the intended use practices).

Examples of researchers and designers we would like to acknowledge in this direction include Dunne and Raby with their innovative usage of radio [5], Gaver and colleagues' many perfectly crafted design explorations, e.g. The Local Barometer [9], and Chalmers and Galani's spot on criticism of seamlessness, arguing for designs that help users make sense of the technology by making 'the seams' visible [7]. What it is with these works we admire is how these researchers and designers go about also technical aspects of interactive systems design in an explorative fashion, and explicit their learnings from these processes a shared resource in the community. The general tendency is otherwise that we, as interaction designers in the field of HCI, focus our research studies, as well as our knowledge sharing practices almost exclusively on one final working solution, without acknowledging the aspects that shaped these solutions. We believe that, in this interdisciplinary community of interaction design and HCI, we would all benefit from richer descriptions of how different professional and theoretical backgrounds meet, and what difficulties and possibilities this brings in terms of working with different forms of digital design materials.

As designers attempting to realize for example (and perhaps especially so) movement-based interaction systems, we are often left with too many questions for how to practically go from learning that an interesting solution exists, to actually replicate and make our own variants of the same form of interaction. If those questions are left out of the community, this raises fundamental questions about knowledge transfer and validity. This paper is a direct response to this situation, as well as to Gaver and colleagues' [10] call for papers that openly discuss what has been *learnt* through interaction design processes, including not only clever solutions and success stories but also failures and challenges.

DESIGN CHALLENGES WHERE MATERIALS MATTER

In this section, we outline a number of design challenges that we have repeatedly encountered in our design efforts, and that all became visible only after starting to actually implement the designed system, and very often not until some complete version is set together. The challenges are structured around three broader themes:

1. Affordances of hardware and casings
2. Experiential properties of software solutions, and
3. Material properties of sensors, radio-signals, and electricity

The purpose of this overview of some of our own previous works is to share observations we have made, and to open up for further discussion on these matters within the community. The examples are all picked from projects conducted in the past, and even though they are all 'just' a few years old, some of the challenges may appear as non-problems in the development context of today. This is also a core aspect that we like to draw attention to: that time-specific aspect of the quickly changing materials of interaction design, often play a central role in research-through design in our field. The dynamic nature of our design materials, especially when making design explorations at the latest forefront of technology, imposes an explicit need for material exploration within design process, as well as challenges in terms of how to document these practices of research. Note also that the examples are based on prototyping in academic settings, and may be less typical for real commercial end-product engineering.

Affordances of hardware and casings

Our first general challenge that we want to bring up concerns the very concrete limitations of hardware, and how this naturally impose restrictions regarding the designs that users may get to experience. We illustrate this by two different examples, the first concerning the changing restrictions of standard hardware, and the second in terms of constraints also on hardware that we design ourselves, but from a perspective of form factors.

Limitations of standard hardware platforms

Our first example concerns the bridging of a higher-level idea for an interaction scenario to the concrete properties of standard hardware platforms, and how this implies that even simple concepts that may seem straightforward not necessarily are realistic to implement on a broader scale.

In a project, ActDresses [15], we explored the potentials of using physical clothing, accessorizing and labeling as an alternative way of controlling interactive systems. This design space ranged conceptually from single on/off mode switchers to more complex configurations with combinations of such accessories, in the forms of e.g. clothes, text labels, pictures, or three- dimensional objects attached to the surface of a device. After a series of explorations for different cases of controlling custom-made robotic devices, we wanted to explore how this same interaction metaphor could be applied also to mobile phone settings. NFC was then a new technology in the mobile domain, existing only on one handset on the market, and

Figure 1. Middle: NFC detects whether tagged shell is near, identifies it and sends the id to a server, which returns software to handheld. Right: Charm is attached to the USB-slot, and software is loaded directly from it.

was immediately considered a straightforward solution for the design problem (see figure 1). However, the way NFC was implemented on mobile phones, at least at the time of these explorations, it could only trace the event of a new tag sensed by the device, and not when tags were removed from the field. Functions for continuously scanning for all tags in range could not be accessed in software. Thus a direct coupling between when a tag was added and later removed from the device was not something that we could implement. We then started exploring a range of other sensors available on the handset, of which most had features opposing the outset of having signs in the immediate physical context of the device they control. Using a camera together with e.g. barcodes would require more explicit reading and therefore a poor match in the sense that it conflicts with the immediate physical context requirement by obscuring the camera. Also sound of e.g. snapping was considered, but considered likely to suffer an unstable and complex detection service.

One of our early explorations was to make use of USB, since it implies physical 'sockets' for positioning of tags. However, although new phones were equipped with mini-USB ports, there were no phones available with standard ports and hosting capabilities. In an explorative prototype we therefore used a MID-device to make a prototype where different tags, such as a tiger trinket and other accessories, were attached via a USB-hub, each triggering a change of the visual theme of the device. Naturally, since USB is not meant for permanent coupling, these markings would easily fall off during ordinary mobile phone usage. In our most successful exploration, we made a solution based on physical shells equipped with small magnets positioned at different locations on the shells. The distance between magnet and magnetometer in the phone could be sensed, thereby triggering events in software. A service program was built that changed the theme on an Android device according to different shell designs.

Our reason for bringing up this design process, which in many ways may appear strikingly naïve, is that it points very concretely to the physical materials we have at hand when we design new interactive solutions. The design concept was motivated by existing use practices, together with use case scenarios and sketches, and despite the rich amount of sensors available on smart phones neither of the demonstrators that we built could be said to provide a convincing design based on current technological standards. Having to hijack the inbuilt compass sensor is not a viable solution, and neither is the use of a technology with a very closed technical interface such as NFC in this case, or one that is not even available on mobile phones today (standard USB). Thus, even apparently simple ideas that are sketched out in an interaction design process may be impossible to implement, often due to overly optimistic conceptions of what can be realized with the materials at hand.

The affordances of surface, shape and texture

Our second example on the theme of hardware affordances concerns the physical appearance of the prototypes we build, and how they get shaped by technical possibilities. Surface appearance and materiality play important roles in 'inviting' people to interact in certain ways, essentially shaping how people may act upon them, and is thereby central to any user experience. However, sometimes these appearances are shaped by technical properties beyond what the designers are able to estimate initially.

In one past project, eMoto [28], we developed a mobile system for sending and receiving emotionally expressive text messages in smart phone settings. eMoto was implemented on a state-of-the-art phone model at the time that made use of a two-handed interaction model with the little toothpick stylus pen. For our project we decided to develop an enhanced stylus that would be an embedded device equipped with sensors. For this purpose we designed a device that would capture users' emotional gesturing so these could be translated into graphical backgrounds on the phone. An ergonomic shape that would fit in the hand was created (see figure 2), and also a hardware design communicating via Bluetooth and having sensors for pressure and movement. It turned out that the hardware needed more space inside the stylus for the battery and other components than we had expected, but instead of giving up on this solution we continued working with the revised shape. The ergonomic and slick shape we had originally seen and thought of as small rounded shape (figure 2), got enlarged to a bulky object that in size came to resemble a dildo (see figure 3a) – something our users also pointed out and a fact that came to (of course) affect their usage of eMoto in public.

In hindsight, we know we should have started by finding out what components we would need to use as well as their sizes and how they would need to be placed in relation to each other. With that knowledge we could perhaps have found a way to rearrange the placement of these components in the mobile phone and elsewhere such that we could have implemented our design idea or at least an alternate stylus shaped more like a handle enclosing the hand. Anything but making our users carry an embarrassing 'dildo'-like device in their handbag. From today's perspective, it may be easy to dismiss this challenge as you now probably had made a completely different solution (making use of inbuilt sensors of a modern smart phone etc), however this was a concrete design challenge in the technological context of 2003-05, and we argue that every moment in time brings new challenges of similar nature.

From an engineering perspective though, eMoto became a fully working system. But from a user-centered perspective it needed to be there for us as in order to experience and understand how the materials we had chosen to work with played out in reality. In other situations, like in a project where we covered sensor nodes in textiles it affected not only the temperature sensor in the device but also the battery and power in a negative way. Designing custom-made hardware for interaction thus depends on factors beyond only novel materials and sensor technology.

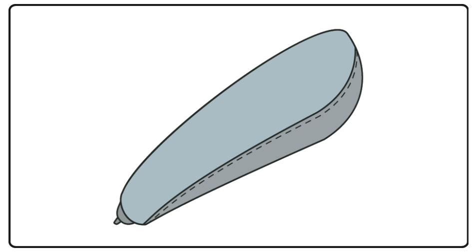


Figure 2. The suggested ergonomic shape that would be small enough to fit in a hand.

This may not be as much of an issue when working with laptop or desktop applications, but when extended hardware solutions are required, this becomes a general and common challenge for interaction designers. Either you are required to design a system for hardware that you have no power in changing (e.g. a mobile phone, as in the first example), or you are part of designing a system where physical components and their configuration is part of the design process. Independently of which, the system that you design and its interactive features will always depend on the physical manifestation of the device it is running on. Also, even if you are personally involved in designing the physical casing, as in the case of the eMoto pen, it is not always easy to change all of its material properties.

Experiential properties of different software solutions

This design challenge concern how most design ideas in the domain of interaction design, could potentially be realized by several different technical solutions. Or as Benford and colleagues phrase it, there can be a difference in what is *expected* by the user, *sensed* by the computer, and *desired* from a certain design idea [1]. Below we give two examples, first regarding the challenge of selecting an appropriate solution, and thereafter the challenge of moving from static sketches to dynamic representations.

What to capture and not to capture

The challenges of selecting appropriate software solutions are perhaps especially evident when it comes to designing systems that capture movement. This since 'human movement' in general, and the inner subjective experience of moving especially can never be fully captured technically. One always needs to make decisions on what is the important part of the movement for a certain system structure, and what technology is best suited for that particular setting. Each solution will have different effects on the experiences users may get from the interaction. It might be a specific gesture that needs to be captured, but in other cases it may be more suitable to capture the size of the gesture, its direction, speed, effort or flow, a whole body's movement in space, or something else.

In the eMoto design, where we wanted to communicate the emotional meaning of the gestures in the form of colors, shapes and animations on the screen, we used Russell's Circumplex Model of Affect [24] as the internal emotional model to connect these two modalities, see figure 3b. This model outlays emotions on a two-dimensional surface of valence and arousal, where each emotion might not be situated the same for all people alike but will have its own unique region. Dimensional models are also more about the experience of emotions than the expression of them, a notion that suited our purposes for eMoto.

What we wanted was to design for the underlying characteristics of how emotions are expressed by people. This to allow for an emotionally engaging experience when creating the messages in eMoto. We did not want to create some new sign language for how to express emotions so that our specific system could understand them. Therefore, for capturing the emotional value of the gestures we made use of choreographer Laban's [18] movement characteristics of the shape and effort of movements to get some guidance in what sensors to use and what to map those sensor readings to and how. In short we came to use a pressure sensor for judging the valence of emotions. This as we from our analysis of emotional body language found that people tend to be more tense when expressing and experiencing negative emotions rather so than for more positive emotions. From calculations of the input from an accelerometer we got the effort, basically the energy required to conduct the gestures. This was in our emotional model mapped to arousal, see figure 3c. Now this combination sounds very simplistic but we want to point out that it is not until this was set up that the actual tuning of these measurements could take place, the tuning and testing that actually sets the experience. In the end this specific part of the eMoto design turned out to be the key part of this design (more details on this work in [8]).

However, we found in our evaluations of eMoto that users felt constrained to use only one expression per message and also regarding emotions, so in a later project we thought we could do without such internal structure and simply re-play users expressions as they were recorded. This was before we came to realize the success of the above-discussed structure. In this case we made an interaction device called the Lega [17], a handheld haptic object for leaving and finding tactile traces in physical locations in an indoor environment. The devices were equipped with pressure sensors and accelerometers for capturing user manipulations, and sets of vibration motors for transmitting haptic feedback to the user when finding a trace. But since what can be captured with an accelerometer and a set of pressure sensors is far from the complete picture the user will have in mind when leaving a trace and also far from, or at least not the same, to what can be expressed with a set of vibrators, there would still be modulation of data when implementing this setup. *'Played out as it was recorded'* is not something that can be straightforwardly done, especially when dealing with the coarse modalities of accelerometers and tactile feedback in the form of vibrator motors.

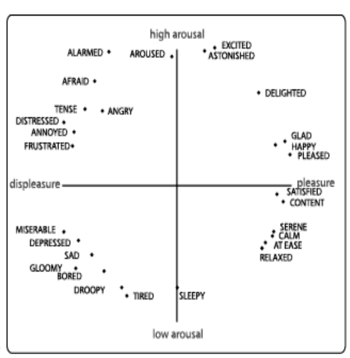
Furthermore, for the design it might not be the right aspect of e.g. the movements that is then captured. Perhaps the effort, the shape, the size or something else would be best to capture for that specific design and then emphasized in the haptic output. Besides, any connection made will carry meaning to the persons using this system and if there then has been no internal structure or any detailed discussion for how to do this connection and discussions on what to capture, it might be that that meaning will be different from what was intended. Or, the system will, as was the case for a few of our users using the Lega design, appear 'meaningless' or too open in what it means to express oneself through that system, which then has the effect that users will start to question how their traces will be understood by some other user, and also what the meaning is of the traces they find. One of our learnings from the Lega project was therefore that some internal model or structure or at least a detailed discussion on how to connect input to output, and what to capture, and what for, is very much needed. Basically, the internal structure of one's system is often important in designing user experiences.

User activity and its mapping to system activity

To continue further into the task of mapping the user activity to some system activity, another material challenge we want to raise concerns how the apparent design of a physical device may allow users to form a misunderstanding of the digital effects of their activities.

3a)

3b)



3c)

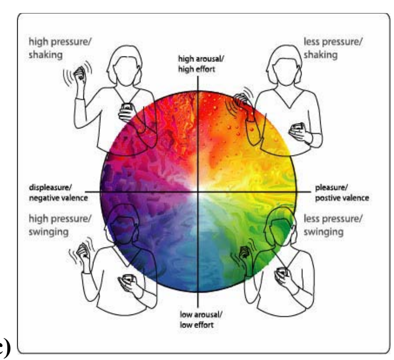


Figure 3a) The eMoto system, 3b) Russell's Circumplex Model of Affect [24], 3c) The eMoto interaction design

One instance in the eMoto design where the users sometimes experienced a mismatch between their actions and system response was when they attempted to express one of the four extreme combinations of pressure and movement: both maximized; one maximized while the other minimized and the inverse; or both minimized. Remember, we were using a two-dimensional model, Russell's Circumplex Model of Affect, as the internal structure from mapping the gestures to the graphics, which for all other combinations than for these extremes helped us create a meaningful and engaging connection between the two modalities. To use the actual circular shape of this model to map pressure and movement to the graphical expressions was thereby central to our design concept. However, a circular shape used together with two variables to move around in this circle, meant that the user never can get to any of the corresponding graphical expressions of the extreme states, see figure 3c. What will happen is that the user will get stuck at the 'edge' of the circle and then stay there, perhaps thinking there is something wrong with the system, while continuing to try to maximize or minimize pressure and movement. Thus there is nothing that tells the user when there are no more expressions to reach, nothing more than that the system stops moving through the animated graphics. If the user realizes that s/he is navigating a circle s/he might realize that s/he will have to release or increase one of the variables in order to continue moving along the edge of the circle, but s/he still will never get to any of the 'extreme' states as a circle does not map to a square, which is what a mathematical and psychological two-dimensional model creates.

This mismatch could be directly traced to an attempt to translate a richly developed sketch made on a two-dimensional plane into a dynamic computational form. A solution could have been to move away from the specific format expressed in the design sketches and instead make expressions more similar to the dynamic forms in a kaleidoscope, i.e. through changing of the shapes rather than navigating in a 2D space of animations. That way we may also have avoided the, for the user, confusing mix of navigational and 'emotional' gestures, although we would then have to abandon some of our ideas of connecting our design to the visual manifestation of Russell's circular model of affect. Looking at the above challenge from a more general perspective, we can see this as a concrete example of how we as interaction designers sometimes face challenges using lo-fi sketching to express designs that may be dynamic over time and also in other dimensions.

Material affordances of sensors, radio-signals, and electricity

Our last general challenge concerns the physical properties of the 'immaterial materials' [27] that interaction designers inevitably depend on, such as the restrictions of sensors, protocols for radio frequencies, and electricity. As designers, it is difficult to get a grip of how to purposefully use these 'materials' as part of designs, and also to acknowledge that users often experience these very concretely in use. Our two examples concern what we see as two recurring challenges for interaction designers: breakups and delays, and the use of electrical power.

Breakups and delays

A delay in response from a system can fundamentally disturb any user experience, and we have found this especially prominent in movement-based interaction. Accepting a slow Internet connection may be disturbing when sitting down in front of a screen, but for movement based systems a few milliseconds of delay can completely destroy the experience of a working system. It is simply not possible to expect a user to wait for a system response when standing in an awkward position, and even a short delay does in such settings often result in users losing a sense of mapping between their actions and system response.

A more mundane example could be the design of a physical volume wheel, but where there is no physical stop or halt to communicate the maximum and minimum audio levels. While this seems to be a non-existing problem within product design of e.g. music stereos, this kind of problem is surprisingly common within the field of interactive systems design. Most of us have probably experienced the situation of persistently pressing a button hoping for a response that we only after a while realize will not happen. The maximum volume level may for instance already have passed or there might be a delay, and since there was no proper indication of this we stand there pressing.

What eMoto really was about was sending and receiving emotionally expressive text messages. In the interaction flow the user was after writing a text message supposed to conduct the expressive gestures with the stylus pen. This, to generate the animated background image for the text. The emotional characteristics, as recorded from the pressure sensor and the accelerometer, were expressed in colors, shapes and animations on the screen while performing the gestures. When the user stopped doing the gestures with the stylus, these animations became part of the text message, which could thereafter be sent to a friend.

What we were aiming for was of course a complete embodied emotional sensation for the user, were the activities of writing and gesturing together would build up for a strong, emotional experience. We had in our initial studies found that the activity of writing up a text allowed users to start thinking in terms of the emotion they aimed to communicate, providing an important initiating step in allowing for a more intense experience later in the interaction. What happened though, was that after having written a text message and it was time to start performing the gestures, there was a sudden delay in the interaction.

In this case, this delay could be traced to the way Bluetooth as a technology had been implemented to connect the phone with the pen. Bluetooth was used in this design since it is a well-established standard for connecting nearby devices.

What we did not discuss or consider together in the design team was the delay Bluetooth requires for 'hand shaking', and therefore such a delay was not designed as part of the interaction. In this case this 'hand-shaking' process took place right in between the activity of writing and adding emotional value through gestures. If we beforehand had understood the consequences, and in the design team had discussed these details of Bluetooth, it had been easy to design that process to take place e.g. while the user was in the process of typing up the message, or at startup of the application. However, as the shared understanding in the design team was that the connection via Bluetooth would just be there and be steady, the initial design did not take this part into consideration - resulting in a user experience heavily affected by break ups and delays. Once the system was built, it took substantial efforts to redesign this process.

But also, it is easy to see these technical requirements, such as the 'hand-shaking' procedure of Bluetooth, only as limitations. In a later project of ours [29], we explored how these properties instead could be thought of as possibilities for design, and turned into system features that trigger users behavior and movements in fundamental ways. In a small series of design sketches we made use of the 'hand-shaking' process of Bluetooth as a resource for new interaction concepts. In one of these sketches, BluePete, where the game is for searching devices to find listening devices and pass over (by connecting) BluePete to them, it very much becomes a game feature that it takes a little bit of time for this to happen. Playing this game we have found how this latency becomes an attribute that affect the players behavior, such as having to hold on to another player to give time for BluePete to 'jump' or adapt a hide and seek behavior towards the other players.

But if the delay is, as in eMoto, not designed as part of the interaction and thereby never explained to the user, the user will most likely come to think there is something wrong with the system. For systems aimed at engaging experiences, where open-minded users and users wanting to be engaged are needed, a sudden delay is probably one of the worst things that can happen.

Power management, consumption and supply

A last example we feel the need to bring up is the fundamental responsibility of dealing with electricity and power consumption as a material property of interaction design, and specifically so for mobile use settings. Even though electricity is a fundamental property of digital artifacts, as interaction designers, we tend to forget that our devices will require electricity to function. This ignorance to electricity in interaction design may seem irrational given our everyday experiences of almost constantly charging our mobile electronic devices, but from the perspective of HCI this situation is probably based (again) on a legacy of the desktop computing setting, where computers could be expected to be connected to the wall. In movement-based interaction settings, this is of course no longer the situation, yet still we tend to exclude practices of charging and saving energy as part of our designs. In everyday usage of mobile devices, for instance, many users have realized that GPS and Bluetooth technologies consumes a lot of power, and they therefore keep these settings switched off by default. Still many of the designs we see do not take this situation into account, and require you to turn on these settings.

In all systems discussed in this paper, power consumption was an issue discussed and addressed, from a very concrete perspective of systems development and design. Reducing the occasions needed for a Bluetooth device to search and connect does for instance reduce power consumption, as well as the amount of data that has to be wirelessly transmitted. In one project, when we worked with wireless RFID readers as part of the design, we quickly noticed that the readings of RFID tags took a lot less power than transmitting the readings via Bluetooth to the computer on which the system was running. Thus the readers were programmed to only transmit certain data when new tags were read, which meant that the software would no longer be able to list all tags currently in range of a reader, or notice if a tag was removed, which naturally also affected design choices in the final system functionality.

In our research efforts, we have increasingly acknowledged energy management as a core challenge, e.g. to design for the charging batteries as part of playing with a robotic toy, or to take into consideration that data transfer via radio consumes power, and from that make design decisions on higher level for when that transfer should be made and how. For eMoto we discovered that the batteries in the stylus pen would last as long as a few days if the connection between the stylus and the mobile phone was broken and the stylus turned off when not in use. But we did not want this activation and deactivation to be achieved by some on/off button or anything else that would take the user's attention away from the experience of the interaction. From a technical perspective we found a solution to do this, where a small amount of pressure would activate the stylus and that it would turn itself off after some time if not being active in terms of pressure. Unfortunately, we found later when using the complete system that performing the initial pressure of the stylus disturbed the interaction. That is, it became complicated to act out gestures that entailed very little or no pressure at all, while it was not problematic at all to do calm movements with high pressure. Which again meant that we had a mismatch between user and system activity (as discussed above).

CONCLUSION: MATERIALS MATTER

It is common sense among anyone involved in realizing the functionality of interactive systems, as programmers, system architects, media designers, that the specific tools and materials they work with on a very concrete level define what parts of a conceptual design that can be realized, and how it can get manifested. A specific programming language or protocol may for instance make it easier for certain actions to be performed, and a particular media format may only allow a certain form of manipulations. Thus, in terms of interaction design, choices made on the technical level of tools and materials are essential not only in the fine-tuning, but also for achieving the fundamental properties of the envisioned design.

In this paper we have presented a series of design challenges encountered in our own work on mobile and movement-based interaction design. In this paper we have discussed how we find this design space extra sensitive to issues of materiality in terms of hardware, software, environmental factors, and the material nature of human bodies as they move in space. These are of course only some of the many and various challenges interaction designers need to address. Arriving at a successful design that allows for an engaging interactive experience that users will come to enjoy using, requires a lot more work than to cover for only the challenges we have discussed in here. We would also like to acknowledge that a central aspect of any successful interactive product will still be the design concept itself and its grounding in a reasonable use case.

One aspect that we have not discussed is also the various properties afforded by different tools such as programming platforms or libraries, which we have seen getting increased attention lately when designing for various operating systems and standards, especially in the mobile domain. When designing applications for other contexts and settings there are yet other challenges to consider. Our main conclusion is however that factors that may cause problems in the interaction are highly dependent on the selection as well as the tuning of how a technology is concretely put to work, which is why we would like to see more of a shared discussion on these issues in our field of research.

FUTURE RESEARCH ACTIVITIES

In a strive towards shared and general understandings, the focus on design methodology is usually staying at the higher level processes of design, e.g. its overall structure, techniques for creative idea generation and interdisciplinary teamwork, not allowing for discussions at the concrete level of tools, materials and technical features that the design work is fundamentally based upon. However, as researchers in this field it gets increasingly important to engage in these more technical design spaces of materials, tools, and resources for the making of interactive systems, so that we all at some level can make use of and learn from them.

There are many different types of materials used in the design of interactive systems that we like to consider here, ranging from classical input and output devices, different types of hardware platforms, various sensors and actuators, different frequencies of wireless communication protocols, and physical materials that in different ways are used to control digital media and applications (textile, metal, wood, rubber, etc.). It is not realistic for individual designers to hold a deep understanding of how all these materials interact and can be assembled into a purposeful user- and experience-centered design process. Instead, an active exploration is required on the level of materials in order to understand the design space that the task at hand may be restricted to. Also, it is not uncommon that a deep knowledge of materials leads to creative solutions, inventions and innovations, which only later may demonstrate real applications and industrial value. This applies not only to the field of interaction design, but is also well known in science domains such as biology, medicine, and physics. Structured experiments on materials from a perspective of interaction design, is therefore important to identify new opportunities for developments that could revolutionize the way we currently use technology. As researchers in interaction design we need to become better at documenting how our designs works out with the materials we use. Every year there is an impressive range of new technical experiments presented at e.g. CHI, but without knowing the details of these often small-scale prototypes, it is hard to bring these technical innovations into new and more complete designs.

We see four activities we would like us as researchers to put more efforts into discussing and openly report on as part of our academic practice in interaction design and HCI:

Material explorations: What are the limits, possibilities, and properties of specific materials, compositions and resources in terms of making interactive artifacts? What experiences can the materials trigger? What potential applications do we see?

Methods for material explorations: How do we achieve understanding and knowledge of a new material, composition and/or resource's specific qualities and affordances? What methods and measurements are needed?

Methods for communicating material properties, and possibilities: How can the material properties be communicated to, and understood by various stakeholders? What forms of representation can be used to in a meaningful way share this knowledge? (demonstrators, video, diagrams, what else?)

Practical application of knowledge gained from material explorations: How may deep understandings of material properties be used concretely as a resource in interaction design? How may material explorations spur and potentially direct, inspire, and allow for new user-centered innovations?

With this paper we hereby hope to have taken some of the initial steps towards a new type of research in HCI, which without moving away from more traditional design practices aims to create a greater understanding of materials, their different compositions, and the digital design spaces they allow for.

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