Inspirational Bits
Towards a Shared Understanding of the Digital Material

Petra Sundström[1], Alex S. Taylor[2], Katja Grufberg[1], Niklas Wirström[1], Jordi Solsona Belenguer[3], Marcus Lundén[1]

[1]Mobile Life@SICS
Box 1263, SE-164 29 Kista
{petra, katja, niwi, mlunden}@sics.se

[2]Microsoft Research
7 JJ Thomson Avenue
Cambridge, CB3 0FB, UK
ast@microsoft.com

[3]Wireless@KTH
Electrum 229
SE-164 40 Kista
jordisb@kth.se

ABSTRACT
In any design process, a medium's properties need to be considered. This is nothing new in design. Still we find that in HCI and interactive systems design the properties of a technology are often glossed over. That is, technologies are black-boxed without much thought given to how their distinctive properties open up design possibilities. In this paper we describe what we call *inspirational bits* as a way to become more familiar with the design material in HCI, the digital material. We describe inspirational bits as quick and dirty but fully working systems in both hardware and software built with the aim of exposing one or several of the dynamic properties of a digital material. We also show how they provide a means of sharing design knowledge across the members of a multi-disciplined design team.

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INTRODUCTION
As a research group tasked with designing interactive systems, we are made up of an eclectic assortment of differently skilled individuals - a multi-disciplined arrangement that now arguably typifies a significant proportion of R&D groups in HCI. Not only do our members consist of the prerequisite software engineers and interaction designers. We also have people skilled in hardware, experimental psychology, qualitative fieldwork and even choreography.

Assembled in this way, one issue the group regularly faces is how to work, collectively, to imagine new interaction possibilities and different applications of emerging technology. Too often we find ourselves reverting to the established sub-divisions of social science, design and engineering, and conforming to a design approach where insights into users' experiences are applied to drive design and development. We may use lab-based or in-the-field studies of people's activities to inform an interactive system's design, or use evaluations of working prototypes to shape new design iterations. However, the actual building of the technical systems, even when iterative, is bracketed off.

Although this approach will be familiar to many and recognized as one that has produced valuable outcomes, we have found it troubling on two counts. First, it feels that much of the emphasis at the early stages of design exploration is placed on what users do and, consequently, attention is directed away from exploring and thinking imaginatively about the technologies. Often the technologies are chosen to solve a user need or support some experience before thoroughly examining their distinctive properties and how they might open up the design possibilities. In effect, the technologies are treated as black boxes, configured to enable predefined interaction scenarios.

Second, we find it leads to a largely linear and one-directional form of communication within our group. At best, the ideas used to open up the design possibilities flow from the studies of users to those who build the interactive systems. The actual implementation of a system remains closed; as a group, we rarely get a sense of the technologies until they are an integral part of a working prototype. Thus, there is little discussion between the skill sets in the group about what the properties of the technologies are and, again, whether they might open up new possibilities. In short, there are few chances in the design process to simply explore the technology, collaboratively.

In this paper, we present our recent and ongoing efforts to address these two concerns. We describe an approach to interactive systems design using *inspirational bits* that aims to foreground technologies as design materials early on in the design process. We see the approach as complimenting the design strategies many of us in HCI have become familiar with and, importantly, encouraging dialogue within multi-skilled interaction design teams. What we hope to convey in reporting our own experiences is that inspirational bits might be seen as a generally applicable method, relevant to groups involved in interactive systems design other than ours.

BACKGROUND

To address what we have felt to be our group's lack of collaborative experimentation with technology, we have in a number of recent projects attempted various strategies to expose and experiment with the properties of technologies. That is, we have sought to identify some of the defining features of a technology and then informally experiment with their configurations. We have found this technological un-blackboxing, if you will, has provided us with a richer set of possibilities when designing interactive systems; in effect, exposing the properties of the technology has opened us up to discovering new and in some cases unexpected directions for our designs.

A recent example is a project in which we used wireless, motion sensors to capture and display the emotional character of a community's physical movements [16]. Initially, we had hoped to use the radio signals from the sensor devices to triangulate location and then visually display the physical proximity between people alongside a visualization of their movements. However, we found this location detection to be far too unreliable because of the manner in which radio signals travel. Instead, through a series of experiments with radio and the sensors, we found we were able to detect and reliably communicate concurrent movements between people. This allowed us to cluster common kinds of movements and visually present them to the users, enabling them to interpret both the kinds of emotions being physically expressed and the prevalence of the expression in real-time.

One lesson we drew from this project was that in starting with a particular end goal in mind we found ourselves thwarted by the particular constraints of radio transceivers - constraints that only became apparent as we sought, unsuccessfully to determine location and physical proximity. Instead of viewing these constraints as a barrier to progress, however, we decided to take a different starting point. In short, we chose to think of the constraints as basic properties of the technology and to purposefully exploit them. Rather than stick to a predefined design and user experience to be achieved with a chosen technology, the system emerged by starting with a treatment of the technology as a material, alongside the other factors shaping the work. The final design came about because we eventually allowed the properties of the technology to play a stronger role in shaping the outcome and be a formative resource driving the overall design process.

On the face of it, such a process may seem unremarkable. Yet, what has struck us in looking back is how this particular treatment of technology as a design resource is not something we have really pursued with deliberate intent, nor regularly brought up in shared discussions among the interdisciplinary members of our design team. Indeed, in our experience the default position has often been to think of the technology as a means to solve a defined problem such as detecting location. It has been only when we have started getting our hands dirty, so to speak, that we have found ourselves tweaking the underpinnings of a technology and almost accidently arriving at some promising possibility. Consequently, such an exercise has not been pursued as a systematic component, where it is deliberately used as a resource for expanding or *"opening up the play of possibilities for design*" (to borrow a phase from another context [2]).

In articulating this, we want to be careful to distinguish our reflections from the conventional forms of techno-centric innovation that HCI has made it its business to address. We see this re-centering of technological concerns as remaining very closely tied to user and design concerns, and human centered/experience-oriented design, specifically. However, in bringing together the user, design and technological concerns, what we aim to explore in this paper is whether we might start from different points of entry – and in this particular instance, from the material and architectural properties of the technology (cf [5], [6]).

RELATED WORK

Most of us will readily accept that algorithms, databases, hardware, communication standards, etc. have their own limitations and possibilities. Embedded in each are properties that are more or less fixed, even though the possibilities for combining them are almost endless [11]. Also, development work rarely starts from scratch; instead, we build using existing libraries, established communication protocols etc. each with their own pre-defined properties.

In this vein, Vallgårda and Redström talk of *computational composites*, alloys made up of a combination of digital material that impose particular properties [18]. Thus, they explain that it is almost impossible to work with the digital material in its most raw form, at the granularity where technology *"handles only voltage according to stored sequences of (practically) discrete voltage levels and maybe input streams likewise of (practically) discrete voltage levels"* (p. 516). Components such as accelerometers, short-range communications etc. build on top of this basic level, and, in turn, become subsumed into yet more abstract interactive systems, such as PCs, mobile phones, etc. Because of this layering of technology, what we find in HCI and interactive systems design is that the particular properties of low-level technologies are often glossed over.

This appears to stand in stark contrast to the techniques and approaches that permeate studio-based and creative design practices [3]. Through sketches, mock-ups and early prototyping, traditionally schooled designers engage in a *conversation with materials* [15]. In the formation of a new idea the materials are worked with is such a way that they start to *talk back*, revealing new opportunities and challenges. It seems, however, that computing technology is a more complicated material for many designers to work with [8]. It is a material that evolves over both space and time [7]. It is not enough to touch and feel this material in any given moment and thereby get to know its properties and potentials; instead; the digital material has to reveal itself and its dynamic qualities when put together into a running system.

One popular approach to supporting developers and designers building interactive systems has been to work on so-called support tools. Yet, most of these systems aim to support designers in the processes of visualizing and refining an interactive system's design (e.g. [9], [13]), not to handle and explore the digital material. There are also a range of systems that enable designers to rapidly reconfigure the construction of their designs, such as varying the color, form and overall build of an object, and also visualize previous versions of a design (e.g. [17]), but still this does not provide access to the full range of possibilities the digital material might offer. The designer remains, in some fashion, removed from the actual technology.

The range of *plug and play* building block solutions provide an alternative, hands-on approach to building systems and, in doing so, go some way towards solving the immediacy problem. These systems, such as Phidgets[1] and Arduino[2], let the amateur hardware developer/maker handle and come to understand more of the digital material's potentials, making the material more open to what Schön refers to as *reflection in action* [15]. But, they still compartmentalize and blackbox basic building blocks such as RFID, Bluetooth, accelerometers, etc. Arguably, this is intended in their design and the basis of their success.

In the following, we thus present a strategy or approach to support the creative and collaborative experimentation with technologies that are usually embedded and thus taken for granted in the design process. As we have suggested, this approach has emerged through our own varied experiences of designing interactive systems in a multi-disciplined group. For example, it builds on our efforts to learn from designers and their use of sketches, storyboards and mock-ups to open up a design space and how they find inspiration in a range of new design ideas. It also draws on the attempts we have made to design *hand in hand* with the digital material [16]. It has been informed too by the increasing number of experiences we have had with hardware kits such as Arduino and Phidgets. Rather than using the kits to build specific solutions, however, our experiences have been centered on getting to know the workings of the technologies and their peculiar properties. Last but not least, it hinges on our processes of engaging all members/disciplines of our group in the generative stages of design thinking.

For the purposes of this paper, the phrase we have adopted to articulate this roughly circumscribed and still evolving approach is inspirational bits. Our idea is for an inspirational bit to offer the basic elements of a technology in a shape that allows all members of a design team to *look* at it, *feel* it and experience it over time and space - exposing all or some of the properties of the technology as a material. The inspirational bits approach thus involves the design team's attempts to work with and handle the technology; exposing its parts, and figuring out how it really works. To communicate the properties of the material to the design team, a fun and inspirational application of the technology is then used. The examples we present are made up of a range of quick and dirty games as we had the idea that the incentives people naturally have to understand the rules of a game would be helpful in conveying technological limitations and properties.

More specifically, this paper describes how we started out to explore Bluetooth as a design material and how we used the feedback we received in our continuous work refining the approach as well as going on to build bits using RFID, accelerometers, and wireless sensor networks. It also describes a two-days workshop to which we invited designers from both research and industry to introduce them to the idea of using inspirational bits in design. From this workshop, we describe how the feedback from one of the more experienced designers has helped us to be clearer about what we want the inspirational bits to be.

INITIAL EXPLORATIONS

Something that contributed early on to this idea of inspirational bits was an exploration we undertook into Bluetooth. Bluetooth was chosen as a technology for a number of reasons. Broadly, we were attracted to the ubiquity of Bluetooth and its status as a standard for wireless, short-range data communication. We felt this provided us with a technology that is often seen as a closed system or black box with numerous taken for granted properties. Again, the intention was not to solve a specific problem using Bluetooth or to achieve some predefined endpoint. It was rather to see whether a focused investigation into Bluetooth, as a design medium, might open us up to anything different and/or unexpected—that is, to find what could be inspirational in this technology.

One thing we found interesting was how a Bluetooth device cannot search and listen at the same time. One device needs to be searching and one needs to be listening for two devices to find each other. Incidentally, this is a property of Bluetooth that is problematic when it comes to peer-to-peer connectivity as both systems may be searching or listening at the same time and therefore not find each other (as in e.g. the MobiTip system [14]). BluePete is an inspirational bit we have built that aims to expose this material property of

1 www.phidgets.com
2 www.arduino.cc

Figure 1. BluePete; on the left a device having him and on the right a device about to get him (being this close)

Bluetooth and also in order to show how it can be played with that the Bluetooth technology needs two clients to be in different modes in order for them to find each other. In this quickly implemented game searching devices "carry" BluePete and listening devices are in danger of "catching" him, which can happen when the two devices are close enough, see Figure 1. Playing this game allows a design team to experiment with the relationship between proximity, connectivity and exchange (e.g. sneaking up on someone, physically hold on to them or taking their phone). Playing the game also allow all parties of an multi-disciplined design team to think of new ways of exploiting these Bluetooth properties and other scenarios where the properties might add to the experience of a system's design.

BTScore is another of our Bluetooth bits. The BTScore bit reveals the Bluetooth devices that are nearby and of what kind they are, e.g., headsets, printers, mobile phones, etc. The bit thereby helps to explain what information one Bluetooth device will send to another, such as device class, services provided and more, and thus reveals a property that might be used for the purposes of design. In BTScore a device's class number allocates a predefined point value when a connection is made with it. To increase their scores users thus have to run around looking for potential Bluetooth devices to connect to. Coincidently, the device class numbering scheme for Bluetooth devices works well with this game design as rare devices tend to have a higher number than common devices, such as 7936 for an Bluetooth Arduino board versus 512 for a smart phone. The bit, then, conveys something of the practical details and the real-world workings of the Bluetooth protocol and, specifically, how devices differentiate themselves through connections and communication.

These examples hopefully capture some of the key ideas we think to be of value in the inspirational bits approach. First and foremost they illustrate the understanding of the material one can get from using them. They show too how this can be achieved with quick and simple systems. For example, BTScore was built in a day or two and relies on a crude graphical interface to convey details about the device class numbering in Bluetooth. Also by presenting the two examples, we hope they capture the experimental quality of the approach. It should be clear that different features of the technology led to different strategies for exposing and working creatively with the properties and constraints. In this way the approach is seen as open-ended and relatively unstructured. Again, the aim is to be generative and to let the material's properties serve as a guide in this creative process.

BITS EXPOSURE

To introduce other designers and researchers to the inspirational bits approach and to get their perspectives on working with technologies as design materials we have presented our Bluetooth bits at two workshops: the Materialities workshop[3] at the Designing Interactive Systems conference 2010 and at the Artifacts workshop[4] at CHI 2010. At both workshops we received very positive feedback. Broadly, the responses suggested the approach was seen as valuable in helping to understand technologies as a medium for design and in generating new design ideas.

At the Artifacts workshop the Bluetooth bits were the starting point for a design exercise; the workshop participants, having used the bits, were told to brainstorm around Bluetooth technology and develop design sketches. In total, a broad range of ideas was generated. Here though we wish to focus on the workshop participants' impressions of using inspirational bits to inspire design. One overall impression was how the ideas that came about seemed to be more grounded in the material. This in comparison to ideas that came out of a similar exercise in the workshop using inspirational pictures of various kinds.

We have also used the Bluetooth bits as a starting point for a design project in the Affective Interaction course given at Stockholm University. Here, the students showed a fascination with the bits. They said they liked how the technology had been transformed into experiences, and how it was the experiences—in this case of Bluetooth, such as the experiences of hunting or being pushed something—that inspired them. However, the students reported struggling to develop their own designs recounting how it was one thing to understand and another to recreate/make use of the bits.

This latter result, in particular, got us thinking about the principal intention of the bits approach. It had never been our intention that the bits would explain how to work with the material; our aim was to use inspirational bits to promote a greater familiarity with the technology and to communicate this knowledge within the design team. In contrast to plug and play toolkits, such as Arduino and Phidgets, we hoped for users of the bits not to become individually accomplished system engineers. Rather, we intended for the design team itself to mark out time to build and come to understand some provided bits and then communicate this knowledge to all members of the team

[3] http://sites.google.com/site/materialitiesdis2010/
[4] http://people.cs.vt.edu/~swahid/chi2010-artifacts/

and subsequently use this knowledge in the design process. We also imagined this to be a cumulative process where teams and individuals in the teams retained skills and knowledge around particular technologies and their bits.

GOING BROAD

With this early indication that we were on to something useful and something design teams possibly want, we decided to expand our exploration to include other digital materials. In the following, we describe our application of the inspirational bits approach using RFID, accelerometers, and wireless sensor networks, further detailing the approach as well as showing how it has evolved. For each technology we first give a short summary of some of the characteristics and properties of the technology and then mention just a few of the bits we built using the technology. Each section ends with a summary of the bits discussed and what property they aim to convey. The presented examples have been chosen, in part to convey the diversity of bits that can come from working with quite different digital materials and how such a diversity can be the source of creativity. Our hope is the range and variety of bits may help to communicate the underlying notion of this work, that the digital material really is a *material*, and a material we need to consider in design like any other.

RFID

Radio Frequency Identification (RFID) is a material that has been experimented with in the past (e.g. [12]). In the work we present, however, the distinctive intention has been to consider what happens when the technology's properties are exposed in the design process and to design teams.

RFID is a technology that uses radio waves for sending and reading information at a distance. This communication occurs between a reader and a tag. The angle of a tag's antenna with respect to the reader's antenna is critical for a tag to be read. The diZe is an inspirational bit that was designed to convey this property. This bit is a board game that consists of a high frequency RFID reader with a very large antenna and a dice with pockets on each side, see Figure 2. In this bit, the reader's antenna defines the area of the game board. A player chooses one of the pockets of the dice for a RFID tag and then throws the dice onto the board. This only gives the tag a one-in-three chance of being read. Because of the direction of the magnetic flow that the reader's antenna creates, current will be induced only when the antenna's tag is perpendicular to the magnetic flow. With these properties in mind, the game can be introduced as it is or in a context chosen for a design task specifically.

RFID might not be as complex as a design material as perhaps some of the other materials presented in this paper. But the diZe in a very good way exemplifies how a bit does not need to be complex. How a bit, in fact, can be something very simple. Through something as easy as varying the size of a familiar technology can make its workings intelligible but also open it up for new ways of thinking about its use. But also how a deeper knowledge in materials offers us the possibility of twisting and tweaking the underpinnings of that material to open up for more innovative ideas. But, in order to be inspirational the question is, if this bit is enough? We will return to this question later in the paper, but what we see here is a possible difference between bits that are designed to explain and bits that are meant to inspire. What we see though is that it may be a range of bits that is in fact what is needed to fully understand the range of possibilities of a material.

Another slightly more complicated bit we developed using the large RFID antenna is our strategic game, inteRFere. This is a two-player game where each player has a set of three tags and must role them in such a way that their tag is the last one read. The game is designed to demonstrate the properties of antenna interference, variations in magnetic field strength and that readers can only communicate with one tag at the time. For example, this bit reveals how two tags on top of one another can cause interference and also that there is an inverse relationship between magnetic field strength and the distance between the tag's and reader's antennae.

To emphasize the diversity of the bits we have built, before continuing we also want to briefly mention BendID. BendID is a game that aims to break away from the conventions of handheld technologies and, in the case of RFID, the common assumption of one-tag-per-user. In

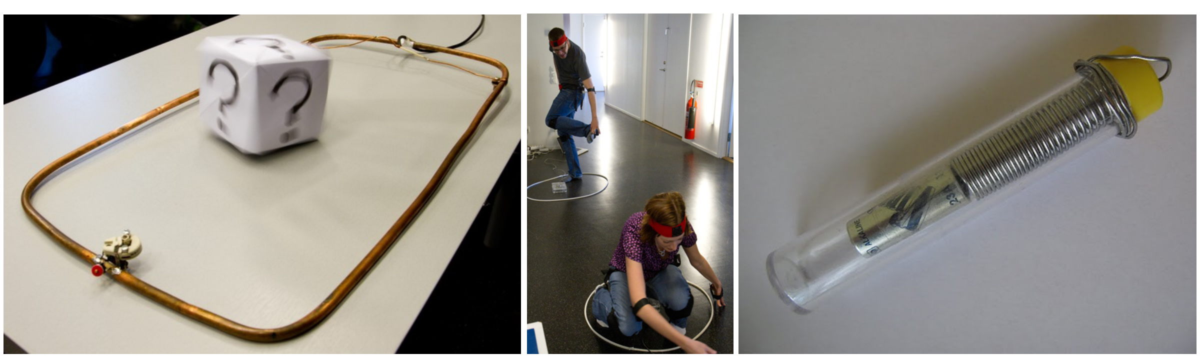

Figure 2. The diZe – a playful presentation of the reading angle of RFID; BendID – a bit where the user wears tags over her whole body; A mechanical model of an accelerometer showing how gravity always is a factor

BendID each user has tags placed over her body. When a game master calls a specific body part the aim is to be the first player to have that body part read without stepping out of a small circle on the floor, where the reader is placed, see Figure 2.

To summarize:

- diZe – demonstrates how the relationship between the tag's and reader's antennae is critical;
- InteRFere – demonstrates the properties of antenna interference, variations in the magnetic field and how a reader can only communicate with one tag at a time; and
- BendID – plays with the conventions of hand held technologies, in this case with several RFID tags distributed over the body.

The Accelerometer

The accelerometer is a sensor that measures change of velocity (acceleration) relative to freefall (or zero gravity) and transforms this measure into a proportional electric signal. The device is usually attached to an object, the acceleration of which one wants to measure.

To visualize the basic mechanics of an accelerometer and also to show how gravity continuously acts on the acceleration that is measured, we found that we needed something as basic as a mechanical model. This model consists of a transparent tube, a mechanical spring and a small weight. One end of the spring is attached to the top of the tube, and the other is attached to the weight. When the tube is moved, the displacement of the weight corresponds to the acceleration that is affecting it. With this tube we wanted to show how it really is acceleration and not movement that an accelerometer captures, something one would think is obvious, but as the accelerometer is used very often to capture movements and also does so rather well [16] the misunderstanding is common. Our test tube, so to speak, also illustrates how accelerometer measurements are always influenced by gravity, as it reveals that when turned towards the ground an effect is apparent even though it is being held perfectly still (see Figure 2). A combination of three such test tubes visualizes the same characteristics of a three-dimensional accelerometer.

Another interesting property we found was how accelerometers in fact sense movement slightly differently, even when moved together. This is a typical issue that can become frustrating in a design situation if it is exact data that is wanted/needed. With our WaveRave bit we aim to show how this can be a design feature. WaveRave is a multiplayer game where the aim is to follow the movements of a leader as closely as possible. To make this game a full body exercise, the accelerometers are attached to the players' chests rather than held in the hand, where it is easier to control the accelerometer using small hand gestures. Players must thus "follow" the physical movements of the leader as best they can. Scores are continuously updated depending on the similarity between a player's accelerometer readings and the leader's. However, imperfect measurements and imperfectly calibrated devices add an extra dimension to the pleasure of playing this game. Players' devices can also be attached differently than that of the leader. For example, by turning the leader's device up-side down, players are forced to perform movements that are inverted to that of the leader.

To summarize:

- The mechanical model - visualizes the basic mechanics of an accelerometer and how gravity always acts on the measured acceleration; and
- WaveRave – shows how imperfect devices can be inspiration to a game and in a way the game feature.

Wireless Sensor Networks

Wireless sensor networks consist of sensor nodes that can communicate and share data with each other in various ways. Each sensor node is a small electronic system containing a transceiver, a microcontroller and different kinds of sensors. For the following bits we have been working with sensor nodes communicating over radio. More specifically, we have been working with electromagnetic radiation, radio waves that propagate in space and travel at the speed of light.

In several of our previous designs we have encountered problems with wireless sensor networks and radio (e.g. [16]). The fact is that radio signal strength is currently one of the most common ways to perform outdoor and indoor positioning. This works relatively well outdoors, but indoors the technology is susceptible to interference from many sources. For this reason, we have found radio particularly hard to think through and design with in the multi-disciplined teams we have worked in. In short, the very immaterial characteristics of this material accentuate the problems; even though the sensors can be seen and their use can be discussed in various scenarios, it is not always easy to see/feel how the radio communication works, and why it is so hard to calculate distance and position (indoors). Therefore, in starting our design exploration into sensor networks, we first set out to try to make this problem more visible, more material.

We built two bits for this purpose, one turning the radio signal strength into sound and one into graphics. The sound bit, RadioSound, consists of two sensor nodes where one is equipped with a small speaker emitting a single tone. The tone increases with the signal strength between the two nodes. Using these sensor nodes one can walk around in the environment noting how the volume changes as the signal is affected by other materials, walls and furniture. Using this bit one can also hear how the signal strength is greatly affected by the human body. In order to also explain how the signal strength measurement is difficult to measure for fast moving and moving sensor nodes, we also decided to build a bit using a graphical representation of the radio signal strength. In this second bit, that later evolved into the GoldRush game, the size of a graphical circle visualizes signal strength. As the circle sometimes disappears, completely, this graphical representation very clearly shows the fluctuations in the signal strength measurement when a node is moving quickly in relation to a receiver node and how a signal stabilizes when holding it still. Also the circle flickers more if the two nodes are far apart.

As one of the intentions with the bits is to turn limitations into possibilities, we explored using these thought of limitations of the radio material as possible features. In GoldRush, for example, a sensor node is hidden, and then looked for by the game's players using a combination of another sensor node and the graphical representation described above. This hide-and-seek game is made more challenging by giving the four players their own sensor nodes and graphical representations of the hidden node. This demands that players cooperate by, for instance, asking others to stand back not to lessen the interference cause by their bodies or sharing their individual graphical representations to find the hidden sensor node faster.

Playing with this bit, we also found that we could use the flickering of the circle as an indicator of whether a sensor node was moving slow or fast. This we used in a second game, Gymkhana, in which the aim is, initially, to move as fast as possible to disturb the signal reception as much as possible and thereby gain points. Players then aim to limit the amount of points they lose by moving between a set of distributed sensor nodes, undetected.

To summarize:

- RadioSound – visualizes the radio signal strength between sensors and how it is affected by the environment and the human body;
- GoldRush – turns the difficulty of using radio signal strength for positioning into a game feature; and
- Gymkhana – visualizes and plays with how the measurement of radio signal strength is different/difficult to measure correctly when there is a lot of movement in the room.

WORKSHOP @ MOBILE LIFE

Our most recent activity targeted at exploring the inspirational bits process has centered on a workshop in which we wanted to get feedback about both the bits and the approach as a whole.

In August 2010 we invited our colleagues and partners at the Mobile Life centre to a two-day workshop where we allowed everyone to experience and learn more about the materials we had worked with so far. Approximately twenty designers and researchers took part in this event. To allow everyone to handle, experience and play with the bits, we divided them into three smaller groups and gave each group time to work with the RFID hardware, accelerometers, and sensor nodes. Each material session lasted for approximately two hours. The first day each group got two such material sessions and one the day after. The second day we also gave each group a design exercise to find out if they felt they could apply what they had learnt.

For this paper, we have asked one of the workshop participants, Anna Karlsson from BORIS design studio[5] in Hong Kong for her thoughts on the idea of using inspirational bits in design and also on the workshop in general. We chose to solicit feedback from Anna for a number of reasons. One important reason was that she does not usually work as a researcher but rather as a professional designer in an international design firm. With her extensive experience in doing design and also working both in multi-disciplined design teams and in collaboration with other stakeholders in a design process we regarded Anna a good person to ask for feedback. Anna has also worked with us on a number of occasions on different projects, and held the role of design research consultant with us. We present Anna's feedback, below, not as a formal evaluation of the idea of using inspirational bits in design, but instead as a means to convey how the idea was responded to in practice, and also as a resource to better articulate our own ideas on this matter.

Below, we have chosen to focus on three themes Anna raised in her feedback: *the idea in general*, *a categorization of the bits*, and *a template for constructing bits*.

The idea in general

First a quote from Anna's feedback to the general idea:

"The inspirational bits approach is about play; it is a positive way to approach a technology. During the play you will learn certain things about the material and the learnings are something you will bring with you to the next step in the design process. Keeping the bits intact could though have the opposite effect for the design team, the team can get stuck on the initial ideas and not be able to move on to the next step. It is therefore important as I see it to point out that after experiencing the bits they should be broken down into their basic material parts; these are what you can use as the foundation for innovation.

The inspirational bits approach is a good way to start a complex project, it helps the team to get a better idea of the material's properties, possibilities and limitations and it also lays the ground for more equal discussions within the group. This is maybe one of the most important aspects you can get from using the inspirational bits approach.

The inspirational bits can also help the design process to become less linear. By integrating construction and production at the start of product development, this cross disciplinary way of working creates a common platform of knowledge for the whole team."

[5] www.borisdesignstudio.com

A categorization of the bits

In her feedback, Anna also explained how she experienced the bits to be quite different to each other and was therefore compelled to categorize them. She explained how a categorization of the bits would help her and others decide what category of bits that should be used in different projects, or different phases of a project. This is something we had started to contemplate ourselves. We had begun to categorize the bits in terms of whether they served some explanatory role or whether a particular property served as inspiration. From this in mind, we found Anna's feedback as an outsider to the approach to be particularly interesting. In effect, we have found it to provide a useful counter-position to our own.

Anna's categorization consists of four categories; *core bits*, *educational bits*, *boundary bits* and *beyond bits*.

Core Bits - "Give it to me in one sentence or 3 secs"

These are bits that can be described in one sentence or quickly grasped in three seconds, Anna explains. An example of such bit is the oversized mechanical model of the accelerometer.

"Using these bits the approach is similar to a design method where you establish the very basics of things as a way to inspire innovation. It is similar to the task of designing a chair where one had to explain what a chair is in one sentence, a sentence that really grasps the concept of a chair. One such sentence could be: 'A horizontal plane big enough for one person to sit'. This explanation opens up for innovation rather than frames you in an idea of what a chair is. The core bits as I see them are about explaining technology in that very same way and thus opening up for innovation."

Educational Bits - "Explain it to me, I am an idiot"

Anna explains how these are bits that share a focus on learning, they convey the basics of a technology. The fewer aspects of the material that are highlighted the better and the easier the bit is to grasp. There should be no value *vis-à-vis* a final design when creating an educational bit. An example of an educational bit is the diZe. The level of complexity in this bit is low, it is immediately or very quickly understood.

Boundary Bits - "Show me the Limits"

The boundary bits are about highlighting a downside to the technology. They serve to break pre-defined ideas about a material and to start group discussions. An example of such a bit is the RadioSound bit.

"The boundary bits are similar to the educational bits as the defining characteristic is learning. The boundary bits are powerful in the way that the whole team gets a full understanding of the limitations of a material before proceeding with a design conceptualization. Another great advantage of the boundary bits is the time that could be saved in the development process of a new service or product: 'show me the limits so that I can avoid traps.'"

Beyond Bits - "Turn the limitation into a feature"

The last of Anna's four categories she calls "beyond bits". This category she explains are bits that are very creative and can trigger a lot of spin-off ideas. They thus tackle the limitations of a material and turn them into features. A good example here is the Gymkhana bit.

"To summarize the first three categories, they are all about understanding a technology, here refereed to as the material. These bits should be built and explained by those who know the material well. The fourth category is slightly different and could be used as the subsequent phase, after presenting bits in the first three categories. The beyond bits could work as a good kickoff in the concept design phase in a development project where the developers get together with the rest of the team to take things one step further. The beyond bits are about making use of the things the design team all learnt from the earlier bits."

We are very grateful to Anna for giving us this extensive feedback; it has helped us to be clearer about what we want the bits to be. We find her categorization useful because it captures the diverse role bits can play at various levels of applicability and complexity; we see how some are more inspirational and others better explain the basic elements of a material. Anna's categorization scheme offers an approachable way of understanding the bits in these terms.

We also agree with Anna that the bits need to be picked apart before using them in design, and that some of them might fit better than others in a specific project and in specific stages in the design process. We are slightly more cautious, however, about Anna's next suggestion, which is about defining the purpose of the bits *a priori*. If we tried to shape the approach into something more structured, we feel we might sacrifice what we see as a fundamental aspect of the approach; that is, its dynamic and open approach to experiencing and exploring technologies and design materials.

A template for constructing bits

What Anna suggests is a template for how to construct bits, a helping guide in creating them. Anna described how she wanted the different types of bits to be well defined. She says: *"before building a bit it should be clear what purpose the bit should have. Should its purpose be to highlight a problem or show a specific characteristic? The template should work as a guideline and checklist but also as an inspirational trigger for developers."*

As a response to this suggestion we want to point out how the digital materials in fact are very different from each other. One can think of the processes of uncovering materials as very structured, where a designer/engineer simply thinks of and builds one bit at a time. And also that the first bits that appear to him or her are the most simple bits and that they, throughout the process, become more complex. Our impression, however, is that it should be quite the opposite. In fact, it is most often in what Anna refers to as the beyond bits, her last category, that we start this kind of process and it is in fact through building these more playful and perhaps more "designed" bits that we begin to understand the material better and begin to pin down the more basic properties of the material. For this to happen it is essential, though, that the process is kept explorative and open ended. It is not that there is a specific set of bits to find. What bits there will be depend on who in the design team participates in the process, the potential limitations/directions, previous experiences and more. In these terms, it is most beneficial if the process can be unconstrained for a short period of time. And, also as Anna suggests, the bits can always be picked apart later on and not all bits need to be used. Most important is that someone in the design team gets to develop a deeper knowledge of the material, or perhaps expands her previous knowledge of that material, and is able to better communicate some of this knowledge to the rest of the design team—something we in fact believe we accomplished in the workshop Anna attended.

CONCLUSION

Inspirational Bits

In summary, the work we report on above has, hopefully, conveyed our experiences with technologies as materials—what we refer to as inspirational bits. We also hope the paper has painted a clearer picture of what we think inspirational bits to be. In short, we see the inspirational bits as a rough way of seeing the technology that allows us to *look* at it, *feel* it and experience it over time and space, exposing all or some of the properties of a material. As we have come to understand them, inspirational bits can be used as one of the initial steps in a design process, making them similar to a technology-driven design process or to Ljungblad's and Holmquist's work on grounded innovation [10] (alt. 1 in Figure 3). In addition, they can also be used to inform a design team about the properties of the materials that might be used in a project (alt. 2 in Figure 3). In any case, we see inspirational bits as something to be used in the early stages of a design process or as early as possible. Also, importantly, we do not see them being used in the first stages of a potential prototype that is to be extended into a full-blown system. Nor do we see them as narrowing down options as in the case of structured methods or design patterns [1]. Rather, they provide a way to produce quick and dirty but fully working sketches with the primary aim of exposing the properties of the material. We have also found that it helps to work with inspirational bits in a playful way to open up the possibilities of a material and not focus as much on its limitations.

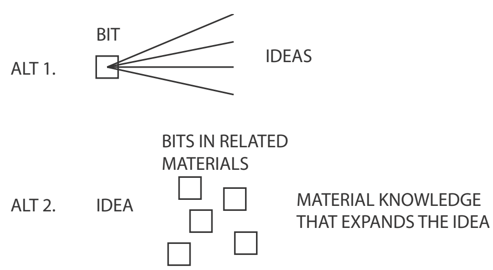

Figure 3. A schematic diagram for how/when the inspirational bits idea can be used, and what for

However, inspirational bits should be quick to build. While building the first bit in a material may take longer time, most of the digital materials are very adaptable and from our experience the second and third bit will take much less time to build. This also means that using these or other inspirational bits in a design workshop they can to some extent be changed there and then to fit with ideas the design team come up with while using them. The idea is to move some of the time and effort we in a design situation at some point anyway will have to spend getting to know materials, to the more early stages of a design process when it can have an effect on the overall idea. By doing so we also believe the total amount of time it takes to build interactive systems in fact will be shorter, in that we will stay away from fighting our material and instead working with it working out the design concept.

Moreover, taking a longer-term perspective, we see the approach having an impact on the longer lasting skills and expertise within a design team. Thus technologies would not need to be repetitively subject to the same investigation, but rather the materials might be added to and taken from a growing repository of bits.

General themes

To conclude, we want to foreground several themes we believe have some general importance to interactive systems design:

Technologies as design materials

Overall, we think there is value in treating a technology as a material in the design process. In our examples, we hope to have shown that unpacking a technology like Bluetooth and exposing at least some of its properties, we can produce some productive tools for a design process.

Design inspiration

We also hope to have shown that there is inspiration to be found in exploring the properties of a technology. Critically, we believe the approach we have taken differentiates itself from a techno-centric perspective. As opposed to the technology driving a design (and, as frequently happens, the resulting solution "looking for a problem"), we have shown that exposing a technology's properties can open up design possibilities and inspire a space for creative thinking. In short, working with a technology as a material does not just limit you to solving problems, it can also be a source of creative inspiration.

Constructive limitations

We think a *technology-as-material* approach provides inspiration because it encourages a constructive view of the technology's limitations or constraints. When technologies are used to solve user-defined problems or achieve technology-defined criteria, their limitations or constraints are usually seen as things to be overcome or worked around. In our examples, we have hopefully shown that the limitations of a few digital materials can be regarded as constructive properties that can inspire design ideas.

Material sketches

We hope the work above illustrates the value of open-ended prototyping or sketching around a technology. In much the same way as Fallman [4] and Buxton [3] describe sketching in design, sketching we see that using technology-as-material opens up the creative options. We find it is also a way to expose the properties of a technology that are frequently overlooked or taken for granted.

System descriptions

Finally, while we recognise the publishing constraints most research is subject to, we feel that a design community could benefit from system descriptions that were more explicit about the properties of the technologies used and how/if they severed as building blocks in the design process?

In sum, then, we believe we have provided some details about Bluetooth, RFID, accelerometers and wireless sensor networks as design materials and also raised some general themes broadly relevant to the interaction design community. Our implications are modest in so far as we recognise the sources of creativity and inspiration in design are many and varied. Nevertheless, we hope to have contributed somewhat to, as Vallgårda and Sokoler express it, a "*better understanding of the space of possibilities*." ([19], p. 4152).

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