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Designing the User Actions in Tangible Interaction

Abstract In our research we focus on the design of 'strong specific' tangible products: products that are dedicated to a particular user, task and context. In doing so, we are particularly interested in the actions side of tangible interaction. Currently, the actions required by electronic products tend to be limited to pushing, sliding and rotating. Yet humans are capable of far more complex and subtle actions: human dexterity is highly refined. We have turned our attention to actions for the following reasons. The first is to exploit the sophistication of human motor skills with a view to product functionality. The second is to explore actions that fit the user's context and work practice from a socio-cultural point of view. And last but not least, we are interested in actions as a source of expressivity and beauty.
This focus on actions and tangibility requires a reconsideration of the design process. Some methods and techniques that work well for screen-based interaction design need to be modified or to be replaced entirely with methods that enable designers to develop a feel for actions.
In this paper we discuss what this focus on actions entail for the design process, and we provide an overview of how it affects methods and techniques for observing users, for analysing user data, for sketching user interfaces, and for prototyping.

Keywords tangible interaction, human actions, anthropology, use context, scenarios, design methods

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1 Introduction

The dominating thinking of tangible user interfaces as ways of turning information from inside the computer into objects for physical manipulation outside it does not sufficiently challenge the design of electronic products. One reason is that such products do not necessarily characterise as information processing devices; rather they are designed to monitor or control something in the real, physical world. We are interested in actions, instead of in representation of information: Actions that fits human skills, actions that allows building of skills, actions facilitates collaborative practice, and a style of actions that is in keeping with existing, non-computer artefacts and the use context.
Two aspects have caused our group to take this particular path into tangible user interaction research: (1) Our background as the user centred design competence of the Danish manufacturing company Danfoss, and (2) our inclination towards the Scandinavian approach to user participation in design.
The industry background means that our focus is on manufactured products, plant contexts, and professional technicians rather than PC-based applications for office-type environments and knowledge workers. Over the last decade we have developed user interaction for heating and refrigeration controls, flow meters, motor controllers, hydraulic equipment etc. for contexts like heating plants, supermarkets, waste water treatment plants, breweries, construction machineries. Such products are typically designed to solve specific control-related tasks. In the sense of Norman [1999] they are 'strong specific' rather than 'weak general'. The people interacting with such products are typically heating installers, refrigeration mechanics, process operators, industry electricians, service technicians, and vehicle operators. They share a crafts tradition with strong respect for the work of hands, and they have a well-developed sensitivity to the physical surroundings they operate in. Touching, listening, smelling, is—besides observing—a central part of their work and a precondition for constantly adjusting their activity.
The participatory design approach makes us constantly inquire into the broader picture of context and work practice and strive to include a user's point of view in all design activities. Through the 90s our group has developed its practice from the one-shot involvement of users in usability testing, to a continuous user dialog staged in user field studies, user workshops, and collaborative design activities (Buur and Bagger 1999; Bødker

and Buur 2002). We build on the Scandinavian tradition of experimental systems development (Greenbaum and Kyng 1991). We presently aim to define and expand the emerging field of design anthropology (ref) to encompass probing and co-designing in the environment of the users, and we regularly move design workshops into the field (Pedersen and Buur 2000). In general, we work from observing users towards redesigning the artefacts, rather than first redesigning the artefacts to then observe the effects on users.

2 Research approach

As this is research into the process of design—the work practice of designers—our primary method is action research, (e.g. Van Beinum 1998). In action research the researchers strive to understand and describe social reality through intervention in practice; by solving a problem with 'the studied', rather than for 'the studied'. In this way the participants become part of the research process and contribute to the results through feedback, discussions, and new actions.
In practical terms, we staged a series of design experiments with a mix of design students, researchers, and industrialists over a 2-year period. It developed from the original proposition that 'designing actions before product' would be beneficial, i.e. focusing on user actions separately from the design of the interface mechanisms that afford such actions. Based on results, participant reactions, and experiences from each experiment we reiterated and improved activities and techniques for the next event. In this way our understanding of tangible interaction and design process developed along with the refinement of appropriate design methods.
The series of design experiments at the University of Southern Denmark (SDU) and elsewhere included:

Student design events (graduate students):
3-week projects Tangible Interaction, SDU (2002, 2003)
2-week projects Expressive Interaction, SDU (2002, 2003)
2-day event Tangible Interaction, TU Eindhoven (2002)
2-week projects Video Studies of Crafts, SDU (2001, 2003)

Research seminars (researchers and industrialists):
1-day workshop, Danish Center for Pervasive Computing (2002)
1-day workshop, Designing Interactive Systems, London (2002)
1-week summerschool, University of Southern Denmark (2003)

In retrospect, all these events have struggled with the same set of research questions, albeit with varying emphasis:
1) How can we re-interpret the concept of tangible interaction to form a vision relevant to industrial products?
2) How does tangible user interface design relate to users' work practices?
3) How do tangible user interfaces relate to the physical interaction in pre-electronic eras?
4) How can we develop methods of designing tangible user interfaces?
These are the questions that we try to report on in the following.

3 Tangible products in industrial contexts

In the literature, several frameworks for tangible interaction can be found (eg. Ulmer & Ishii 2000). Categorising tangible user interfaces in a framework can help overviewing the field, but often at the cost of understanding the full potential of the individual project. To create a framework, one must either make it very extensive to include every detail of each project, possibly at the cost of immediate comprehension, or make it simpler and clearer at the cost of details.
In our research, we have met several projects challenging our understanding of the term tangible interaction. Being familiar with the terminology in the framework by Ullmer and Ishii (2000) and terms such as "containers", "tokens" and "tools introduced by Holmquist, Redström and Ljungstrand (1999) to describe and understand the projects, we find that some projects simply cannot be explained in terms of these frameworks and require a different viewpoint to be understood as tangible.
In a recent lecture with students, introducing the "Emerging frameworks for tangible user interfaces" (Ullmer and Ishii 2000), we gave them each an A4 sized description of a tangible user interface concept written by participants of our DIS2002 workshop (Djajadiningrat et.al. 2002), supported, when possible, by a video clip. We asked the students to present the project and place it within the framework. Some projects fit nicely, some fell outside of any category, but most of the projects had a tendency to span over several categories and the students felt that excluding one, would not give proper justice to the character of the individual project. These findings are consistent with Ullmer's and Ishii's closing remarks.
The map shown in Figure 1 was produced in discussions among the participants at the DIS 2002 workshop. It pinpoints the concerns: That the type of tangible user interfaces in focus here deal with control rather than creation (of information), and actions rather than objects.

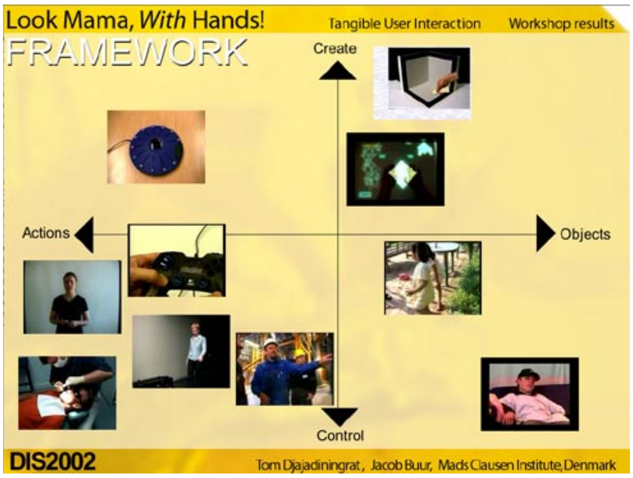


Figure 1: Map of tangible interaction designs, produced by participants at the DIS 2002 research workshop

4 User actions are skilled

Most interaction design today focuses on simplifying the required actions thus reducing the skills requirements. With keyboards and buttons the main challenge for the user is to locate the key to be pushed, and to do this sufficiently fast. Locating keys is solely a cognitive effort, whereas the pushing itself is a monotonous string of motorically trivial actions. The same can be said for the type of tangible user interfaces in which users move tokens as carriers of information on a flat surface: Actions are larger but hardly require skill, let alone that they allow building skill. This underrating of bodily actions appears to have its origin in the prevailing understanding that mind and body can be regarded as separate entities; that knowledge is different from skill:

'Generally speaking, The Western model of person provides a conception of the mind as the internal, nonmaterial locus of rationality, thought, language, and knowledge. In opposition to this, the body is regarded as the mechanical, sensate, material locus of irrationality and feeling.' (Farnell 1999)

With the move towards physical interaction we are interested in exploring the very opposite: basing interaction on actions that require the user to build bodily skills. Clearly, this requires an investigation of what aspects of skill are valuable to interaction design as well as an understanding of how actions required by computerized artefacts differ from those required by everyday objects.

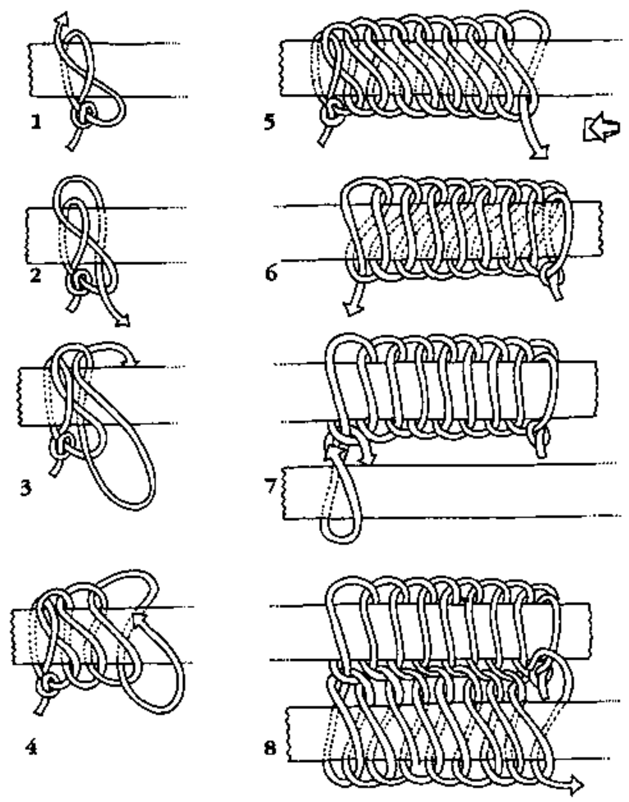


Figure 2: The step-by-step procedure for weaving the bilum, a string bag popular with the Telfol people of central New Guinea (from MacKenzie 1991). Although highly illustrative, a craft like this cannot be learned by following diagrams, but only through introduction into a context that affords learning in practice.

Even a commonplace action like tying shoelaces requires skills far superior to those of pushing keys. The anthropologist B. Farnell favours the term embodied knowledge to underline that knowledge is not only in the mind, but also in the body:

'There are also numerous mundane techniques (skills) such as ways of eating, dressing, walking, sitting, digging, planting, cleaning, cooking, bricklaying, and fishing, all of which vary according to culture and local conventions (...) Such dynamically embodied signifying acts generate an enormous variety of forms of embodied knowledge, systematized in various ways and to varying degrees, involving cultural convention as well as creative performativity.' (Farnell 1999)

It would not do justice to the value of actions, however, to interpret embodied knowledge as merely a mundane kind of knowledge that is not worthy of being formalized, written down and learnt in a cognitive manner. In fact, the opposite seems to be true: embodied knowledge defies being formalized in a cognitive manner and therefore has value in its own right.

The irreplaceable quality of human skill is central in the work of another anthropologist, Tim Ingold, who analysed the traditional craft of making a string bag, the bilum, among Telfol people of central Guinea. The production requires weaving of an intricate pattern of plant fibre string, Figure 2. It is a craft that takes years to master, and it is introduced to the children of the people at a very early age.

In experiments with his colleagues, Ingold attempted to learn making bilum-type knots guided only by verbal instructions and step-by-step diagrams. This proved immensely difficult and frustrating, and Ingold concludes that the skill of bilum making is not based in conscious rules or any form of representation:

'As in any craft the skilled maker who has a feel for what she is doing is one whose movement is continually and subtly responsive to the modulations of her relation to the material. Conversely, the clumsy practitioner is precisely one who implements mechanically a fixed sequence of instructions, while remaining insensitive to the evolving conditions of the task as it unfolds.' (Ingold 2001)

When users of computer keyboards or electronic products with buttons depress keys, the computer does not recognise any variations between fully depressed and not pressed at all. Here is no opportunity to exercise 'subtle responsiveness to the modulation of the material', and thus no opportunity to build skill.

Figure 3 shows an example of a skilled task from the industrial domain. A machine operator in a brewery routinely tests the function of two empty-bottle sensors in the bottle filling station. These sensors prevent that bottles, which are not empty, reach the filling point. Every half hour the operator needs to run a test in the running production to check that the sensors indeed register and discard the faulty bottles – automation is potentially unstable. He takes the test bottle (an ordinary bottle filled with water and marked with a band-aid around the neck) and places it between the other bottles on the conveyor belt. When the first sensor registers, the system rejects the test bottle, and the operator picks it up and puts it back on the conveyor belt. When it passes the next sensor, and all works correctly, the system shuts down. The operator then deactivates the sensor, turns the machine back on, and removes the bottle before it reaches the filler machine.

To us, this sequence makes the impression of a 20 second choreography of precision and skill, one action following the other in one rhythmic, flowing movement. The layout of the work area sets the frame for the procedure, but the operator can gradually improve his skill and refine the rhythm.
By trying out the sequence ourselves we quickly discovered that this is indeed a skill action: The very act of pressing the test bottle in between bottles on the running conveyor belt is not quite easy, and to perform the entire sequence swiftly needs training to keep up with the system.
As a framework for analyzing the craft aspect of industrial work, we have used Ingold's five qualities of human skill:
1. Hands, eyes, tools are not used; rather they are brought into use through patterns of dextrous activity.
2. Skill is a property not simply of the human body, but of the total field of body, mind, and richly structures environment.
3. Skilled practice is not just the application of mechanical force to exterior objects, but entails qualities of care, judgement, and dexterity.
4. Skilled practice is learned through introduction into contexts that afford selected opportunities for perception and action, and through scaffolding, rather than through representations and schemas.
5. Making arises within the process of use – the creative process of environmentally situated and perceptually engaged activity – rather than in the design that precedes it. (Ingold 2001)
With this extended understanding of user actions as skill we can set ambitious goals for tangible user interaction design: We want to create products that address the body, that allow users to learn skilled operation through bodily action and to let them perfect this skill over time until it becomes second nature.
This may be in direct opposition to the prevailing easy-to-learn paradigm, but we feel that this is indeed a necessary step to take to radically improve tangible interaction design. Since many industrial, computerized products show how difficult it is to make the easy-to-learn mantra come true, we are interested in directing the seemingly unavoidable learning effort toward bodily rather than cognitive skills.

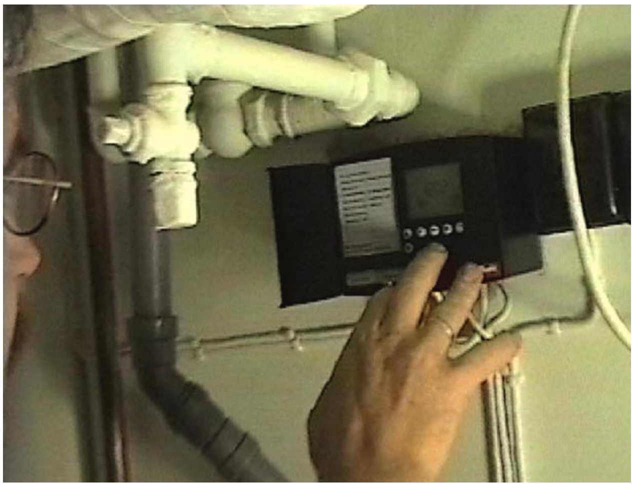


Figure 4: A heating installer confronted with a modern electronic heating controller with display and push buttons. There is no possibility of transferring skills from their work practice.

5 User actions are situated

In industrial settings, like heating plants, breweries, factory floors, there is a striking discrepancy between the non-computer apparatus and the electronic controllers and computers. Whilst the traditional apparatus and tools leverage the action skills of the operators, the interaction with the computer equipment is based almost exclusively on button pushing and display reading. When observing how skilled operators handle such electronic equipment, it is evident that the style of interaction bears no relationship whatsoever to the emphasis on hands and tools that is characteristic for their work tradition, Figure 4.
Now, we can analyse this situation in terms of the local interaction breakdowns – buttons are too small and provide too little tactile feedback, icons are unaccustomed – but this will only provide us with very limited options of improvement. Instead we need to look at the larger picture of context: The environment, the social setting, and the work traditions:
'To understand the body movement as a component of social action, then, one must see in social reality: not muscles, bones, and angles of displacement, locomotor patterns, or position behaviors (Prost 1996) nor even an arm moving upward, but a woman greeting a friend, a man trying to attract attention, or two young men thumbing a ride.' (Farnell 1999)
In her trend-setting work on office workers and copy machines, Suchman has pointed out how purposeful human actions are inevitably situated, shaped by the particular physical and social circumstances (Suchman 1987). Rather than based on preset plans, humans choose what to do and how to do it in response to the opportunities of the moment.
Paul Dourish supports this view that tangible user interaction relates to context:
'Tangible and social computing are arguably aspects of one and the same research program. (...) Both approaches draw on the fact that the ways in which we experience the world are through directly interacting with it, and that we act in the world by exploring the opportunities for action that it provides to us—whether through its physical configuration, or through socially constructed meanings. In other words, they share an understanding that you cannot separate the individual from the world in which that individual lives and acts.' (Dourish 2001 pp. 17-18).
In our work we rely on video in ethnographic field studies to investigate how the current environment affords, facilitates, and exploits the user's actions, and how that relates to computerised devices and networks in that environment. One of the cases we have studied is that of a heating installer replacing a broken pump with a new one in the heating system of a family home. This is a task of 1-2 hours that involves much physical activity with hands and a variety of mechanical tools, Figure 5.
After having located the problem to the pump residing among numerous pipes in a poorly lit boiler room, the heating installer first unpacks the new pump and gathers all necessary components on a table or on the floor nearby. This helps him physically map the new solution he is establishing: Fittings, joints, stop valves, pump body etc. Then follows a number of preparatory actions: He assembles suitable fittings using spanners, prepares threads for watertight connections with his fingers. Confident that the new solution will fit (the new pump is a new model with different dimensions), he blocks the flow of water, sets a bucket in place

Figure 3: The 20-second choreography of a brewery operator performing a sensor test at the bottle filling station. Introducing a test bottle on the conveyor belt, checking that the system shuts down, deactivating the sensor, restarting the system, removing the bottle, all in one swift, rhythmic flow.

Figure 5: The replacement of a heating system pump. An intricate pattern of tools, hands and actions adapted to the confined space around the installation. Some actions are quick and repetitive, some controlled and forceful.

below, and disconnects the old pump. Then he builds his new assembly into the pipe string, constantly adjusting joints to satisfy his professional perception of functionality and aesthetics. Tools, hand positions, and actions shift in an intricate pattern to make best use of the narrow space around the pump. Some actions are quick and repetitive (fastening a joint); others are slow and forceful (tightening a union). It is evident that he has a nuanced feeling for what force is required at each instance to make joints tight yet not strain the materials.

The context—including the space, the materials and the traditional tools—challenges and constrains, yet at the same time guides and facilitates the installer's actions. The installer's actions cannot be seen separately from the context in which they occur. Whilst supposedly computerized artefacts are to offer functionality 'at the press of a button' the actions they require typically do not respect this symbiosis of context and actions.

6 User actions have a history

In the larger context of society and history the context of people's actions and interactions with technology does not stay constant; it changes with time. The way in which designers create user interface mechanisms does depend on the technological means available, but it is also deeply rooted in the values and ways of thinking about human-machine relationships prevailing in society and in the design community at that time. In previous work we referred to this as interaction styles, and we have shown how the interaction styles have changed through the 70-year history of Danfoss industrial products (Øritsland and Buur 2000):

Machine Cowboy era 1930 – 60
Analog Professional era 1960 – 80
Digital Hacker era 1980 – 2000
Augmented Molly era 2000 –

We do not claim that these style descriptors hold beyond Danfoss type products and contexts, but the exercise of identifying interaction styles does seem to help designers clarify the values they want to design by and generate appropriate interface concepts.

It is, however, striking how over the 20th century many products have undergone a similar pattern of change: The physicality of interaction is reduced, the number of functions increases, and the coupling between form, actions and functions becomes less transparent.

In a new experiment with graduate students, we have studied interaction styles of telephones. By collecting archetypal products from different eras in telephone museums, and by creating style posters we are able to characterise interaction style periods, frame the dominant actions, and to use this as a starting point for designing new digital tools with richer actions, Figure 6.

In the early days of telephones, the 'Magic Connector' era 1870 – 1930, hand actions were gross and forceful; cranking the generator required some practice to establish connection. Later, in the 'Routine Caller' era 1920 – 80, when telephones became a commodity of every home, the interaction pattern stayed constant for a long period with one hand lifting the receiver, and the other rotating the dial in small, repetitive circles. The 'Life Chatter' era 1970 – 80 brought push button telephones with extended functionalities. The dialling actions turned into staccato tapping. Today, in the 'Information Explorer' era 1980 –, the entire telephone is the size of a palm. And one hand does all the action: Pushing buttons with the thumb and lifting the device to your ear.

Based on the interaction style studies, each of four design teams created a concept of a modern digital telephone albeit with interaction styles from each of the four eras. With this they showed how it would be possible to preserve some of the action qualities of earlier times.

7 User actions carry emotion

In her paper 'Emotion and Movement' Maxine Sheets-Johnstone argues that bodily feelings and emotional feelings are closely intertwined. Bodily movement is expressive – as clearly shown in studies of animal behaviour – but at the same time one experiences movement. One is moving and being moved in the same instant:

'When serious attention is turned to kinetic form and to the qualitative complexities of movement, emotions are properly recognized as dynamic forms of feeling …' (Sheets-Johnstone 1999).

This is in tune with Hummels (2000) who claims that actions do not only carry functional but also affective information, for example, you can give something to someone carelessly or lovingly. Hummels explores the poetic qualities of actions and movements in a collection of interactive installations where people can create music by moving their hands through sand, leaning on cushions etc.

Laban made a thorough systematization of movement quality by analysing bodily and mental effort in dance and human movement at work. He distinguishes four basic components in an aesthetic of movement (Laban et.al. 1974):

1. The management of weight - strong or light?
2. The flow of movement - free and flowing or bound, restrained and controlled?
3. The use of space to achieve movement – is movement direct or indirect and flexible?
4. The use of timing and rhythm - is the movement executed smoothly or rhythmically, quickly or with restraint?

Sheets-Johnstone points towards Laban analysis:

'Movement notation systems allow empirical study of a whole-body kinetic process in ways that would provide insight into the differential dynamics of emotions. In Laban-analysis and Laban-notation especially, both the what and the how of movement is notated, thus not merely a flexing of the knee or a twisting of the torso (Laban-analysis), for example, but the manner in which the knee is flexed or the torso is twisted (Laban-notation or Effort/Shape).' (Sheet-Johnstone 1999)

In a student project on video techniques, we asked each team to portray a particular crafts person and his/her work: Baker, blacksmith, florist, hairdresser, massage therapist, taxidermist, violinist, and watchmaker. The students then found video sequences showing characteristic movements for each craft, pooled the clips, and tried to group them according to action qualities across the crafts. Figure 7 shows how one team of students used Laban-analysis to characterise the actions.

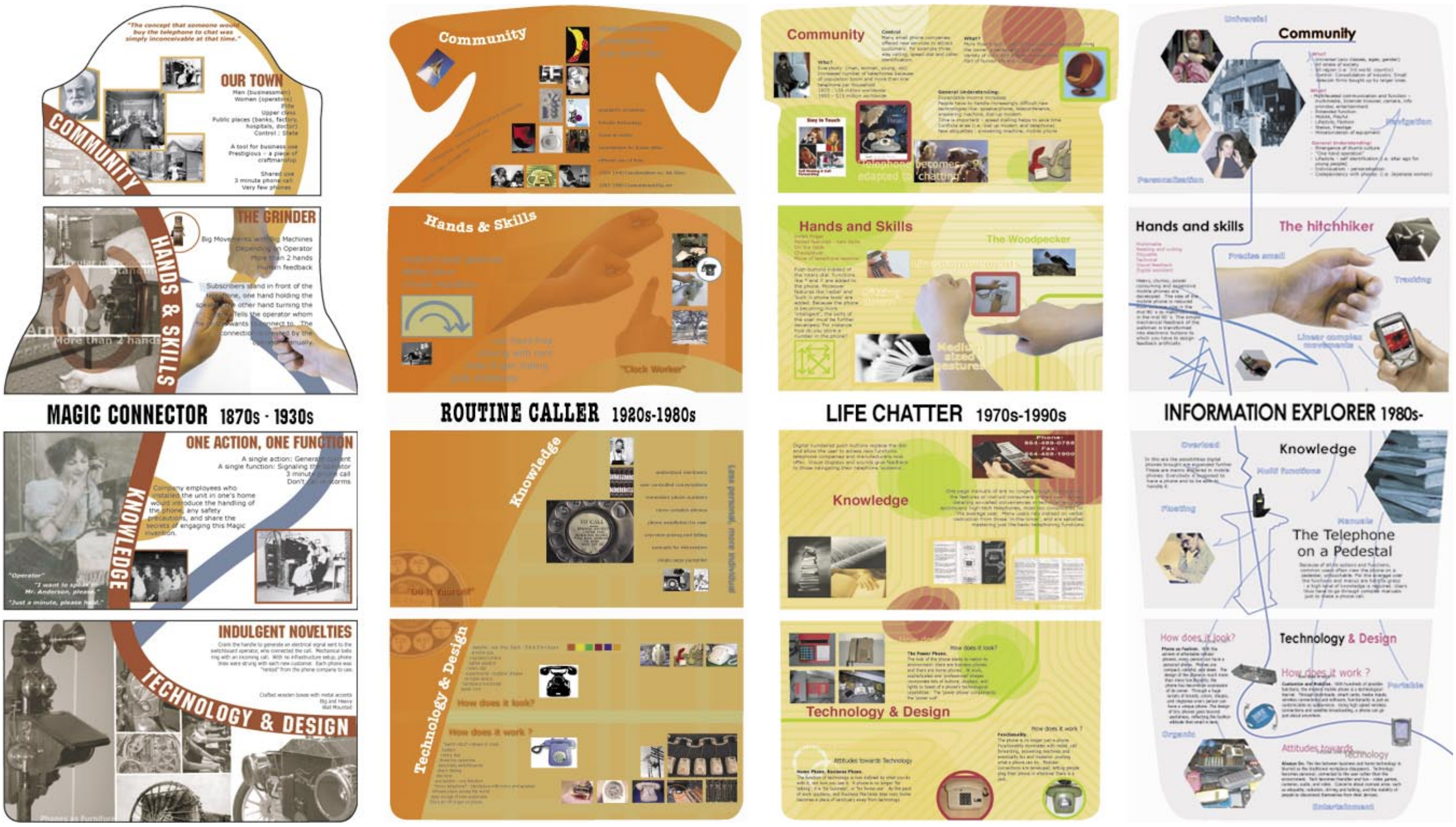


Figure 6: Interaction style collages produced by graduate students as a result of museum studies.
Below is an example of a student design of a mobile phone in the Magic Connector style.

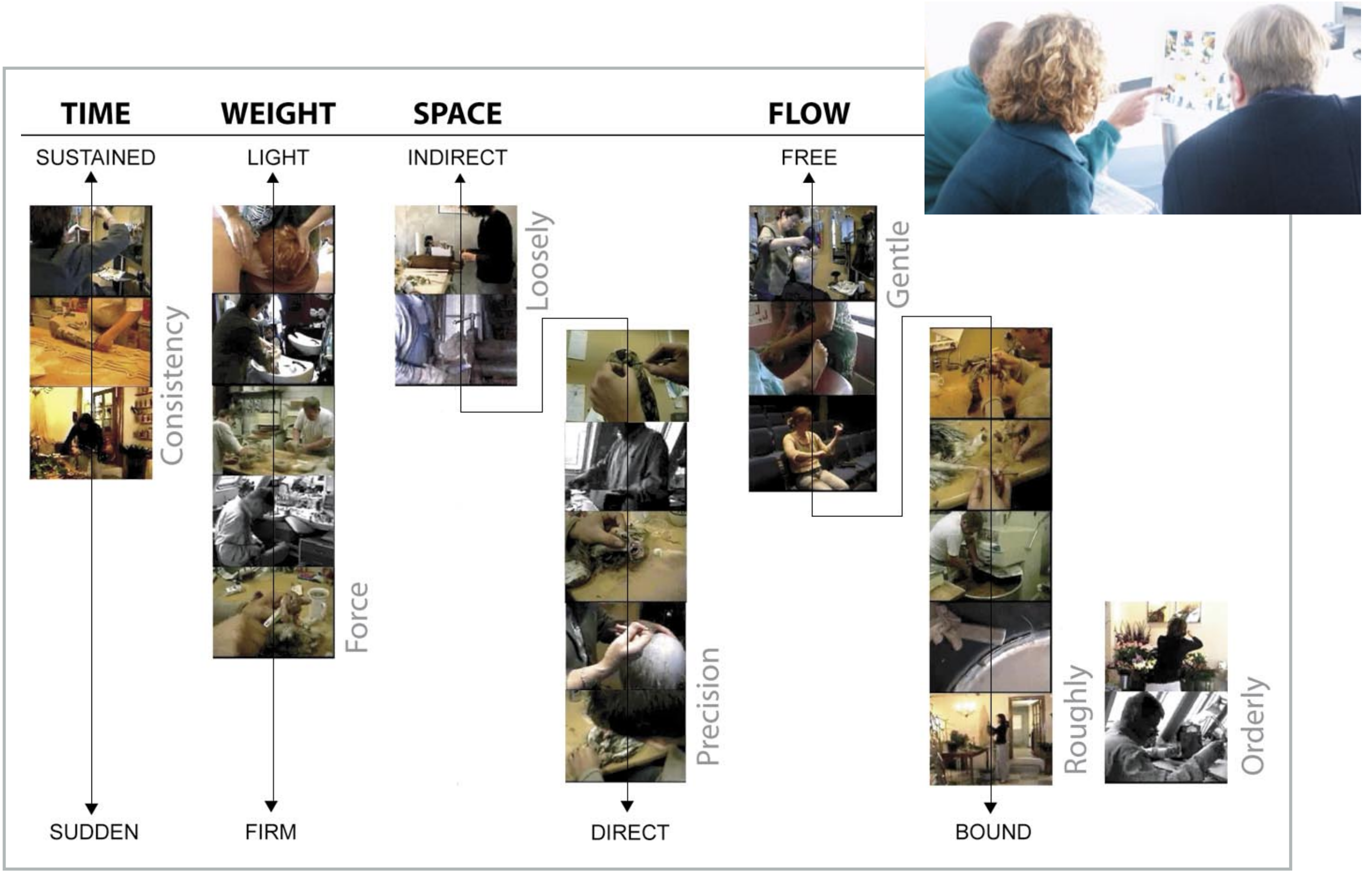


Figure 7: The poster takes Laban terms to structure qualities of actions across a set of traditional crafts: Baker, blacksmith, florist, hairdresser, massage therapist, taxidermist, violinist, and watchmaker.

8 Designing engaging and meaningful user actions

We set out from the working hypothesis of 'designing actions before product'. With this we wanted to force ourselves to be explicit about actions before linking them to physical design solutions. In fact, the avenue of designing user actions is not open to designers. All we can do is design the user interface mechanisms that afford such actions and hope they will emerge once people start interacting with our product. Nevertheless, we argue that the field of tangible user interaction needs a strong focus on user actions to succeed, therefore considering actions before product seems a good strategy, until we learn more about the relationships between functions, form, and actions.

This is in keeping with the shift in interaction thinking moving away from the idea that meaning 'lives' in the artefact towards meaning that is created in the interaction. As Dourish puts it:

'This world is already filled with meaning. Its meaning is to be found in the way in which it reveals itself to us as being available for our actions. It is only through those actions, and the possibility for actions that the world affords us, that we can come to find the world, in both its physical and social manifestations, meaningful.' (Dourish 2001 p.116).

We will briefly present our approach and discuss the techniques we have developed.

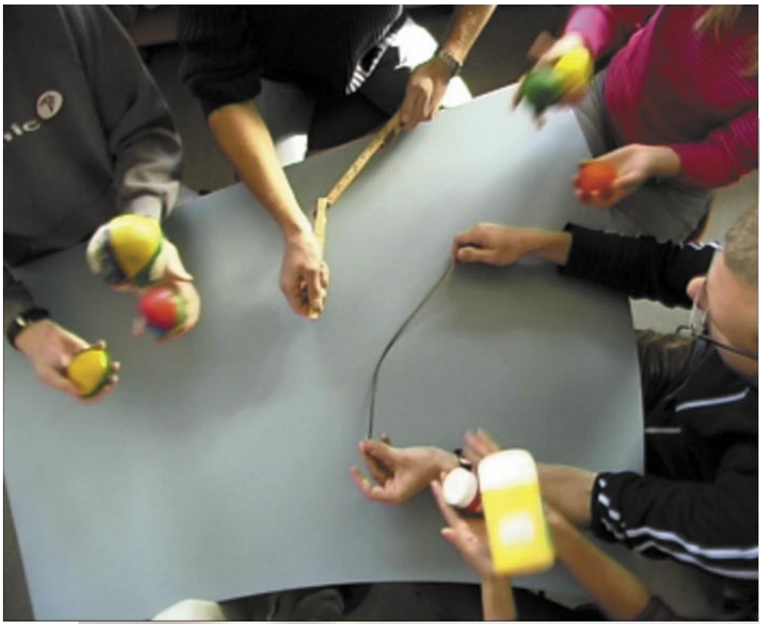
8.1 Everyday objects as source of inspiration

As button pushing is such a commonly accepted mode of interaction it requires a conscious effort to abandon fixed notions of what user interfaces should look like and focus on the rich potential of human actions. We have found that taking people's own experience with handling everyday, non-electronic objects as a starting point can work as an eye-opener and provides a rich source of action inspiration. We simply ask participants to bring along a favourite object that they are good at handling, run a show-and-tell session, then ask them to compare qualities of actions.

It does take some discussion to express qualities, but a grouping exercise helps: With classes of 30 students we ask the students to circulate freely in the studio, handling their objects continuously, and then cluster in groups with actions of similar experienced quality – as if they were live post-its in a grouping exercise, Figure 8a. Then we ask each group to come up with a quality key-line.

We have noticed how these quality statements differ between teams: some are very mechanistic, some metaphoric in their descriptions. One group of students for instance brought together the four actions of tooth brushing, turning a screwdriver, drawing circles, and flipping Hamburgers. They described the activities like this:

> 'Controlled effort: Making repetitive circular movements and adapting the force to the feedback'.



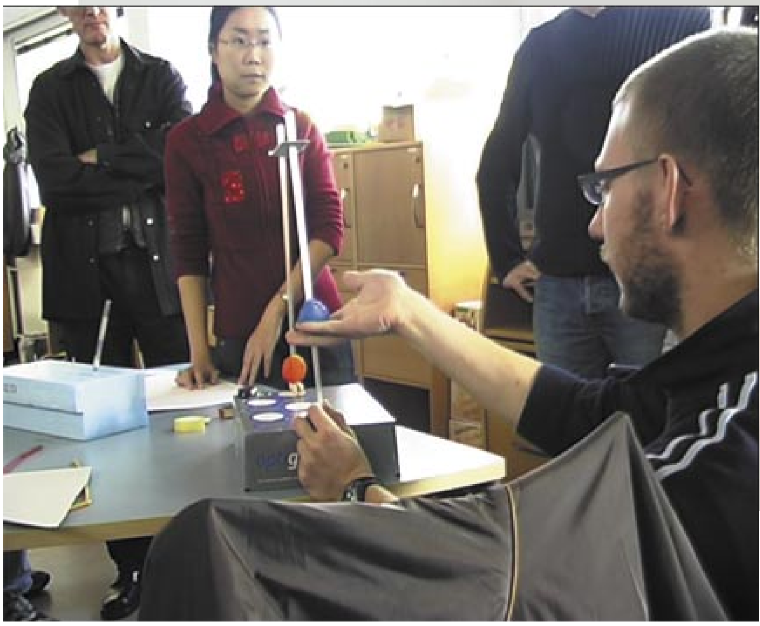


Figure 8: Three steps of a ‘design actions before product’ process:
(a) Actions with everyday objects,
(b) hands-only scenario without product,
(c) actions with tinkered sketch.

Under the headline »Accurate adjusting« this group joined around similarities in their fine and precise adjustment of force, either joggling or measuring. The joggling movement was transferred into the interaction design of a video recorder. Pushing the ball upwards with a light force means play, adding more force means fast forward. Handling a tape measure was used as a means to set the timing.

In contrast, another group found a metaphor to describe their actions of spinning a Frisbee, juggling two balls in one hand, playing with a coin, moving a rubber band between fingers:

’A dog continuously chasing its own tail/movements to pass the time’

Here we are in line with Ingold’s analysis of the case of bilum makers:

’... the accomplished bilum maker does not experience the movements of her body as being of a mechanical nature. Far from answering to commands issued from a higher source, they carry their own intentionallity, unfolding in a continual dialogue with the material. Telefol people liken this movement to the flowing water of the river.’

Clearly, the poetic, metaphoric expressions serve the design process much better.

8.2 Ethnography through the macro lens

For some years the influence of anthropology has taught us that the narrow focus on how humans operate computers is not sufficient to grasp the complexity of interaction design. Ethnographic field study techniques - in particular participant observation and video recording - help designers understand the broader context of work practice and socio-culture as background for human actions. Designers have learned to shift from telephoto shots of interaction in usability labs to wide-angle views of users in their natural environment.

For tangible user interaction design the wide-angle view is still valuable, but as designers we need an additional, detailed focus on hands and actions to get a feel for skilled hand actions and motion preferences of users. To stay within the focal length metaphor, designers need not only the wide-angle views of real work practice but also macro footage of how humans use their hands with familiar tools and objects, Figure 5.

’The current challenge for anthropology is to develop modes of registration and specification that will facilitate the learning and analysis of action, allow records of visual-kinesthetic action – alongside records of speech – to become a normal part of fieldwork practice, and so lead to the presence of enacted forms of knowledge in ethnographic accounts.’ (Farnell 1999)

The action possibilities that we design into products depend on our assumptions about the use context. That is, the environment that our design will influence. Elsewhere (Pedersen et al 2003) we plead for moving design activities into the use context in what we have called ’field design sessions’.

8.3 Video wall analysis

To understand and discuss action qualities it is essential to be able to compare the actions. As actions are highly temporal, we have experimented with a technique of multiple video loops running on the same screen. This technique we have coined video wall, and it takes inspiration from Mackays ’Video Mosaic’ (Mackay and Pagani 1994) and our own ’Video Card Game’ (Buur and Søndergaard 2000).

On the screen 12 – 20 small-size (160x120 pixels) video clips represent the actions discussed. Each clip shows a loop of an action, and so the video wall not only shows dynamic information that still images cannot convey, but also shows this information in parallel, providing an opportunity to compare actions that normal video does not. Moreover, similar to post-its, the video clips are

Figure 9: Participants at the DIS 2002 workshop working to classify actions on the video wall.

freely movable across the screen, allowing the participants to collectively group and regroup the actions, to create clusters that emphasize differences and similarities, Figure 9.

8.4 String of actions and hands-only scenarios

Use scenarios – short stories of projected use of future designs – have been recognized as a powerful means of relating ideas to use context and work practice. In industrial design circles the acting out of use scenarios (Burns et.al. 1994; Brandt and Grunnet 2000) has become increasingly popular for exploring and evaluating ideas on interaction qualities, more so than the written stories format widespread in HCI circles.

So far, most scenarios focused on the social interaction, the interaction with the use context and the sequence of events. Tangible user interaction requires particular attention to hand actions. For this reason we have been working with hands-only scenarios as a supplement to full-body acting of use scenarios. The hands-only-scenarios focus on what actions the hands will do to interact with the designed artefact. We experiment with hands-only scenarios that show actions only as a vehicle to design a string of hand movements without yet considering the physical shape of the product. This can lead to a lot of hand-waving, but we have found two ways of strengthening the activity: Asking all team participants to present their string of actions simultaneously encourages them to synchronise and be very exact in each action. Introducing a video camera to record the actions can further strengthen precision and rhythm, Figure 8b.

One method for mapping actions to functions is the ‘Interaction Relabelling’ (Djajadiningrat et.al. 2000). Like the analogy methods in industrial and engineering design that transfer problem solutions from one domain to another, Interaction Relabelling introduces everyday objects with rich mechanical actions to inspire designers to think of physical interaction. – If the heating controller were this toy gun, what function would the trigger action represent?

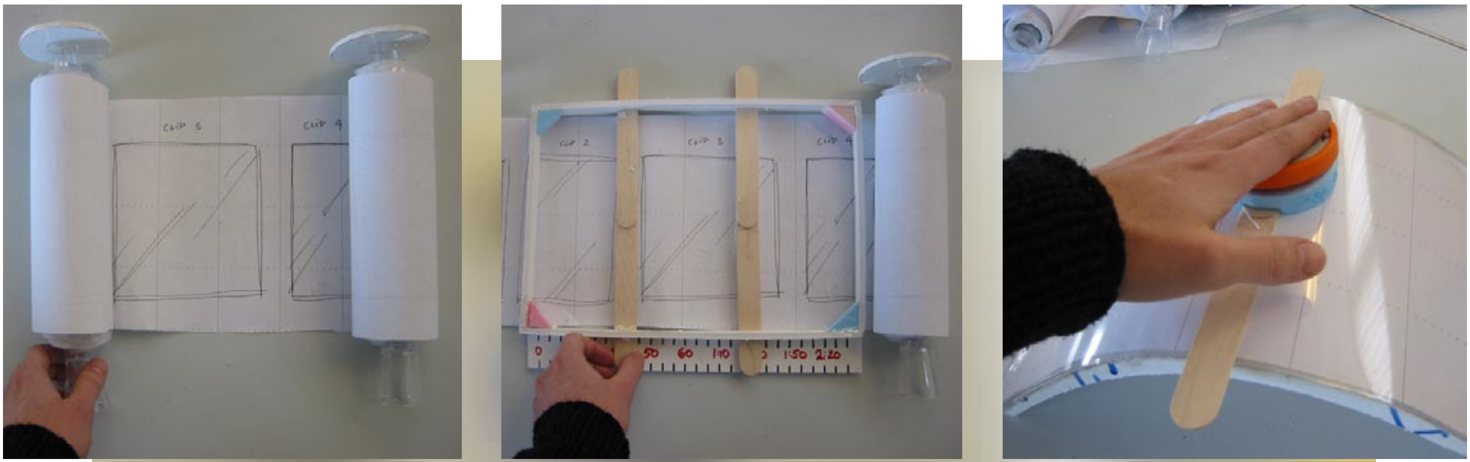
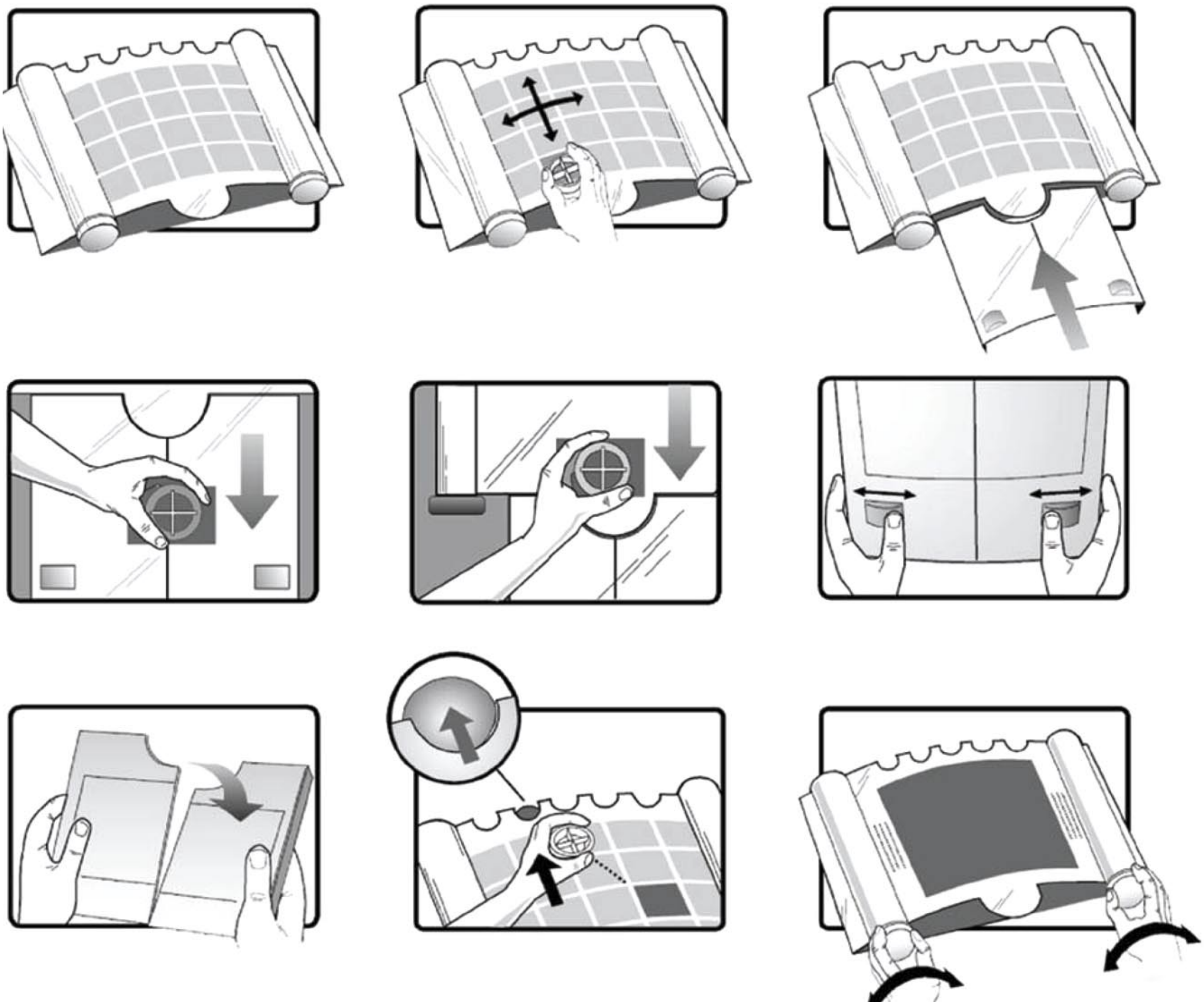


Figure 10: A tangible, collaborative video editing tool. Two prototyping levels from a student design project.



8.5 Tinkering tangible interaction sketches

Freehand sketching - although very powerful for quickly capturing and exploring design ideas - falls short of supporting tangible user interaction design in that the paper cannot adequately express interaction nor the feeling of actions. In stead we have grown fond of 'Tinkering', a technique in which the designers use simple, cheap material like office supply and arts things to quickly build 3D representations of their ideas, Figure 8c. The same technique can be applied successfully in collaborative design sessions with users, like the 'generative tools' of Sanders (Sanders 2000).

9 Conclusions

Starting out from a somewhat diffuse interest in user actions, we now realise that we have opened a 'can of worms': User actions are skilled, they are situated in use context – and in a historical context, and they carry emotions.

Based on a string of design experiments with graduate students, researchers and industrialists, we have developed a set of preliminary design techniques, which with some success supports our strategy of 'designing actions before product. This strategy – although in itself a contradiction – helps designers move beyond the one-eyed focus on cognition and computers to a sensitivity towards hand actions and physicality.

The challenge in understanding user actions is a huge one. Anthropology is presently awaking to the need for a new field of anthropology of human movement, and we anticipate that the combination of such a research area and industrial design will be able to lift tangible interaction design in ways similar to what the symbiosis of cognitive psychology and computer science did for Human-Computer Interaction 20 years ago.

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