CHALMERS


# Improving small labs

## A case study of the t2i lab

*Master of Science Thesis in the Programme Information Engineering*

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## ABSTRACT

This project deals with a common situation in smaller research laboratories, where the projects have centred on ideas which in time have matured. In this situation, the question of where to go from there becomes important and this project attempts to study the situation and develop methods for finding development possibilities in the relevant areas.

Important areas to consider are of course technical development possibilities and customer demand, but considering intellectual property and organizational strength as factors with impact on the future of the research laboratory.

In this project, the focus is on a case study of the TableTop Interaction Laboratory (T2i lab) at Chalmers University of Technology in which the methods of this project were formulated and tested. The result of this case study turned out quite well, with both formulating a procedure for using the methods as well as the resulting analysis providing useful information on which directions the T2i lab can develop in. This allows for a stronger theoretical foundation when making strategic decisions for the future of the research lab.

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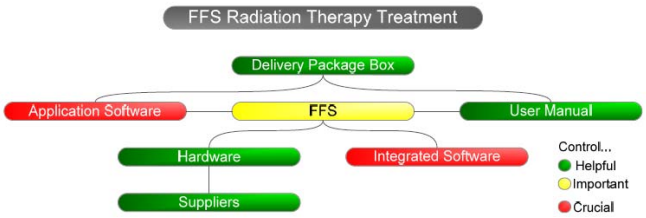
# INTRODUCTION AND RESEARCH QUESTION

## PROJECT INTRODUCTION

This thesis work was created around the idea of examining the status of the projects at the TableTop Interaction Lab (t2i lab) (Fjeld,2008) at Chalmers University of Technology, Gothenburg. The projects and the lab itself will be presented in more detail below. This project originates in and revolves around the concept of the t2i lab as a Living Lab (Vinnova,2007). Because of this it was important to get an overview of a set of processes which have developed organically next to each other, with the common denominator being the context: the t2i lab. Even with this common denominator, however, the projects are self-sustained entities and need to be handled as such. In this context, that would mean activities within a given context.

The structural vacuum is a representation of this organic growth, as these projects have come to coexist rather than as part of a greater plan. The lab environment itself has the potential to provide parts of a structure which can augment existing projects and support new ones. This in itself is nothing new, it simply means that a structured environment will provide a clear set of rules for working in that environment, which is clearly beneficial as long as the rules do not constrain creativity but endorse it, where able.

This has also meant taking into account the status of the projects themselves, in order to establish the situation as it is, and practical prospects for the future, as well as their implications. Intellectual property management, as it turned out, was also an important part of reconstructing the environment, in some contrast with the open research conducted in the various projects. It stands as natural, then, that an overview of the available resources is essential, with several advantages to gain: an inventory, research goals as well as more presentable information.




**Picture 1: A chart of suggested development for the ForceFeedback Slider, with regards to a radiation therapy application**

## TABLETOP INTERACTION LABORATORY INTRODUCTION

The first foundations for the t2i lab was laid in 2004, after Bruce Thomas of Adelaide, Australia came to visit and Morten presented his projects. Tabletop Interaction was more or less defined as a name with regards to Morten Field's current projects, at that point. Also, as a part of his terms of employment there should be an area made available to research, which is what turned out to be the premise of a laboratory with a stable location.

The first projects at the lab was the thesis work of Wolfgang Mähr as well as a number of "d3projects", an early correspondent to a bachelor's thesis for Computer Science students. The lab grew from there, and became a focal point for projects and competences in Tabletop Interaction, with initial projects such as: AMME, Augmented Chemistry, BUILD-IT, Forcefeedback Slider, and SpaceCat.

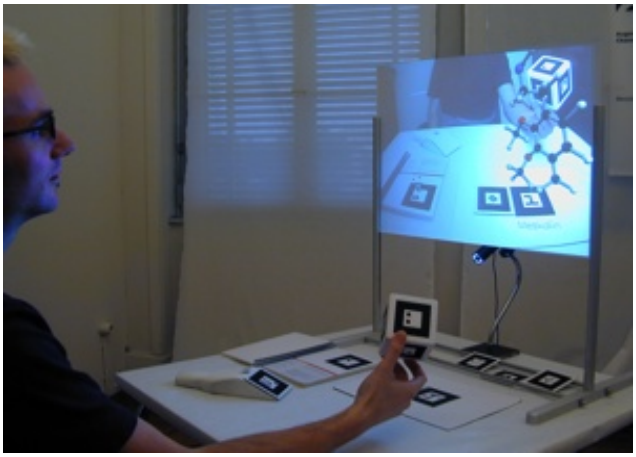
At this point, the lab as it is shape, with a graphical profile and a webpage. Old projects were brought into the lab, and continued. More recently, the lab has started to establish more corporate connections and routinely supplies D3 projects as well as a number of Masters Theses, which creates a stable working environment.

## T2I PROJECTS

There are several projects in the t2i laboratory. Some of them are older, some newer, and they are started by a number of different persons. This diversity makes generalizing about the projects hard, except by noting the fundamental connections to tangible interaction. However, most of them can be categorized into three different groups, as follow below. One thing they have in common, though, is that they are situated in a small lab; the t2i lab, and they both share attributes and contribute to the information that is a part of this case study.

## VISION-BASED UIS

The vision based UIs have in common their focus on tangible visualization, that what you do with your hands is immediately shown to your eyes, enabling natural hand-eye coordination. The three projects below are examples of how to bridge the gap a standard computer interface creates between hand and eye.



**Picture 2: The Augmented Chemistry project in use.**

### AUGMENTED CHEMISTRY

This project is a learning aid aimed at chemistry students aged 12-15, to help them visualize and thus understand molecular configurations.

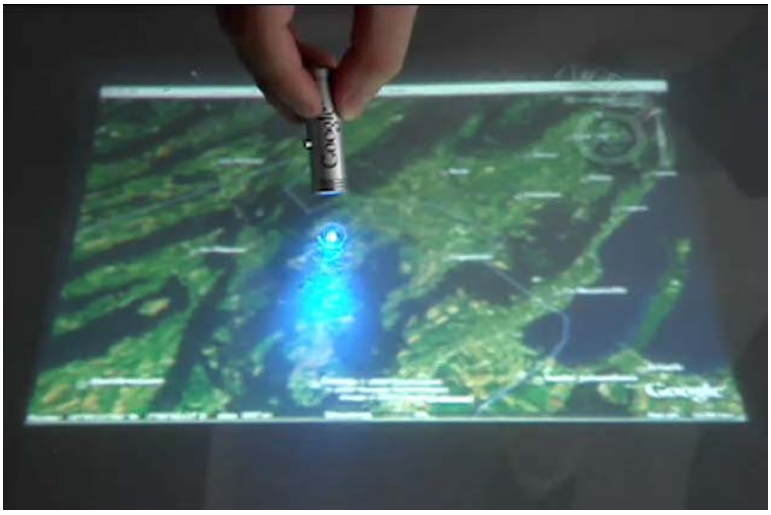
### 3D HAND TRACKING

The purpose of this project is to create a library that will allow its users to control 3D applications by using one or both of their hands.

### ORTHOLUMEN

Ortholumen is based on using visible light source(s) that are manipulated in above the table. Since light sources are defined by their position, orientation, and direction in space, they may give additional DOFs to tabletop input.

The Ortholumen project is in the phase where it is streamlined to MacOS functions in order to make it more stable and portable. While this is a very short-term goal, the ambition is to make an “out of the box” product which will be easily and robustly useful for the potential users.



**Picture 3: Using Ortholumen to navigate Google Maps**

There are a number of useful project developments at this stage, one of which is having a systems analyst or software engineer study the project and determine how well the architecture is suited for open development or efficiency. Another is to have an Interaction Designer study Ortholumen and determine whether or not the project is useful at all, and if so why it is, and what kind of use and user it is suited for.

## TOUCH-SENSITIVE UIS

The common denominator for these projects is of course touch – and expanding on the natural sense humans have for intuitively understanding the tactile properties of a tool. Using this touch and feel principle, these three projects exemplify easy to use tools.

**Picture 4: One of the touch-sensitive UIs; a ForceFeedback Slider**

### FORCEFEEDBACK SLIDER

Based on an in-house design - a generic force feedback slider (FFS) - we have realised a software application simulating a catapult. As users interact, they receive both tactile and visual feedback.

### SPACECAT

SpaceCat is an elastic desktop 6DOF input device. It has been shown that this could be beneficial to virtual scene navigation.

### TOUCH & TYPE

Touch&Type is meant to overcome many of the drawbacks encountered with conventional integrated pointing devices. Touch&Type combines a conventional keyboard with an extended touch pad whereby the touch pad's sensitive area is formed by the surface of the keys themselves and thus can be made as large as the whole key area.

## XXL DISPLAY UIS

The three projects below are all larger UIs beyond the tabletop scale, and are intended to facilitate collaborative work. They, too, follow the same principles as other t2i projects and aim to be natural interfaces.

### COLLABOARD

Collaboard is a virtual whiteboard system, used for remote collaboration. It aims to bring a more personal approach to remote collaboration, with also projecting the image of the persons currently interacting with the Collaboard to get a more tangible feel.

## SKETCHING

This is a table where infra-red pens are tracked on the display surface, allowing a number of people to collaborate in a variety of sketching tasks, aided by remote-meeting tools possibly linking multiple tables at different locations.

## BUILD-IT

The Build-IT system is a large scale collaborative system where any number of people can gather around a table to work together with a variety of tasks such as distribution planning and construction.

**Picture 5: A model of the Build-IT system**

## OTHERS

These are other projects which do not fit any of the major categories above. They are still clearly focused on Tangible Interaction, of course.

## EMOTION

Emotions influence our cognition and could be a key for improving user experience. The measurement of these can be done in different ways. This project explores the possibilities to measure emotions via mouse movements.

## MOBILITY

Firstly, we investigate the user experience of the mobile internet. Secondly, we explore the potential usability gaps when switching mobile phones.


**Picture 6: One of the focuses of the Mobility project is to examine how users behave when switching cell phones.**

## LAB ENVIRONMENT

The t2i laboratory is the physical location where these projects are carried out. Since Tabletop Interaction is a multidisciplinary field, the laboratory is equipped to handle working with electronics as well as programming and design.

Part of the t2i lab is designated physical area which is quite unique at Chalmers when a variety of perspectives are compounded. The first of these is that it has a designated physical area. A lab occupying a physical area is rare but not unique at Chalmers, but it is still an important characteristic. Other important factors include a shared body of related skills and knowledge, continuity in research, and an established connection to the university. These factors work in synergy to create a stimulating creative environment, and especially so at a single given location, much like any given working environment.

The lab itself is situated within the department of Computer Science and Engineering (CSE), but is kept accessible for the students who work there. For use in the lab, a number of workstations are made available. These workstations are used by whomever needs to use them at the time, with some more suitable for working with electronics, and some more suitable for more brief projects.

There is also a webpage which binds the issues of the lab together. It keeps track of the projects, past and present, as well as the people who work on them, or have done so. In addition to this, it keeps track of publications associated with the t2i lab and its projects.

## RESEARCH QUESTION

What kind of problems does a small research laboratory face, and how does one analyze and deal with them?

## MOTIVATION

The basic motivation for this thesis was the perceived need that the research at the t2i lab mostly was in the stage where the concept had been identified and prototyped, but not yet developed towards a customer. This resulted in a sense of a middle ground, where the idea was established, but there was a lack of both potential customers and intellectual property. By finding potential development areas for the various projects two good things can be achieved: making student projects within the greater projects more meaningful and strengthening and expanding the intellectual resources of the lab. Once this is fulfilled, future work might allow more commercial applications of the projects.

## SCOPE (CONSTRAINTS)

Given the sheer size of the projects involved, it would not be possible to go through all of them in this thesis. Therefore I focus on the ForceFeedback Slider as one of the strongest projects, as well as the t2i labs role as a Living Lab (Vinnova,2007). While the scope can be considered narrow in comparison to the available capital, it is motivated by the replicability of the concept as well as situational constraints which appeared throughout the course of the project. These constraints mainly concern the possibility to get commercial feedback, and during this project the ForceFeedback Slider project was accentuated by both t2i research as well as commercial clients. This is why I believe it is a natural focus and constraint.

## PROJECT PLAN

The project plan, with a detailed time plan, was discarded due to changes in the project focus and altered time constraints. More information on this can be found below, in the Conclusions chapter.

# BACKGROUND

The situation of the t2i lab was not clearly defined at the point of finding it, much like any work in progress. It is likely that many small laboratories share these same qualities of not having a fully carved niche. Approaching a situation like this inspires to ask several questions quite naturally, when confronted with potential. Seeing a laboratory develop with an umbrella principle of nurturing the potential of a research area rather than the focused intent of the more common version, a more commercial lab, is a stark difference. From one perspective, it is the difference of an idea of an application and the idea of a method. One is concerned with ends, the other with the roads to them.

The questions, then, which need be asked are equally different. When one has the idea of the application, the research question is how to get to this desired goal, and this is usually a straight-forward process with strong engineering methodology to support it. The other question, when the method is the idea, is how to find the application(s) of the idea. In difference to the other, convergent, style of work, this is by necessity both divergent and convergent. However, this doesn't automatically mean that we are looking at a double work situation; that is what this project is about, finding how to effectively find a focus to converge efforts towards while still utilizing the possibilities of an open-ended research environment.

## SITUATIONAL BACKGROUND

The t2i lab in particular is what encouraged this study. There were several situations in which it was deemed beneficial to find more answers. Looking at these situations separately opens for and, in a fashion, encourages isolating and perhaps prioritizing these different aspects. That, however, was never the intention of this project, which aims for a more descriptive approach to the situation than to rank these possibilities among themselves. It can perhaps be argued that this ranking should be part of the project, but I argue that choices like these are too situational to constitute a generic method. Since part of the project is to establish methods for dealing with this situation, such priorities would be considered counter-productive.

## EDUCATIONAL ASPECT

How does a small research lab like the t2i lab affect the university that it is connected to? This is an interesting question with different perspectives. Both students and faculty have, as always, something to gain from the option of working with or within a small research lab. There is also the flipside to consider: what does a small research lab to gain from a strong connection to the academia. There are several obvious answers to these questions; such as a larger pool of competence being available to the university and thesis opportunities.

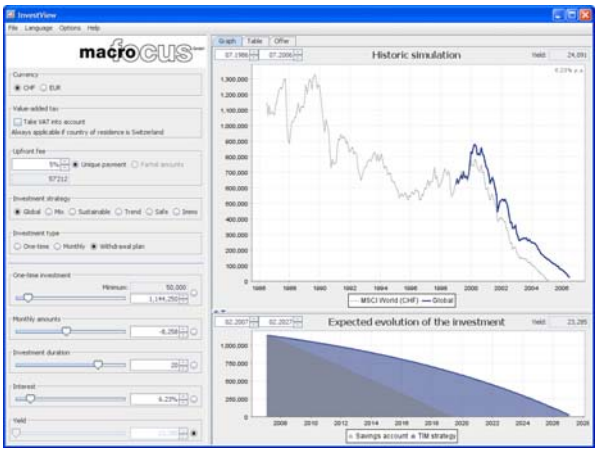
Unfortunately, largely due to time constraints, the educational aspect did not get as thorough an investigation as would have been necessary to properly draw conclusions. Why, then, was this not made a priority? It could be for many reasons, but the one I would present as the likeliest is that there simply was not enough data to warrant a significant portion of time.

## COMMERCIAL ASPECT

Another point of interest is how a small research lab should deal with the commercial aspect, how to form sellable products and cooperate with the industry. Small research labs face difficult situations and choices of how to plan their research, continuity and which ideas are commercially viable. In common situations like this, it is also necessary to know how to approach commercial research groups to share information and start mutually beneficial cooperation. These processes, and more, are interesting studies of setting a course for a small research lab, that are vitally important but most often not part of the natural agenda. These choices and situations need a guide to clarify what is important.

## RESEARCH ASPECT

Central to any research lab, large or small, is of course the research activity itself. Smaller labs face difficulties compared to larger and more established ones, however, such as coping with intellectual property build-up and the disposition of man-hours on the project portfolio. Part of being a smaller lab is establishing intellectual property in a field where it is quite possible that the intellectual property is largely staked out, and beating this with "height" in the inventions is central. Tied to this issue is also the one to consider how resources should be divided; on basic research in the field, or more focused research towards a clearly defined goal. Finding the right mix for this situation will be central for any small research lab that wants to establish a solid foundation.




**Picture 7: MacroFocus, a commercial application of the ForceFeedback Slider.**

## LIVING LABS

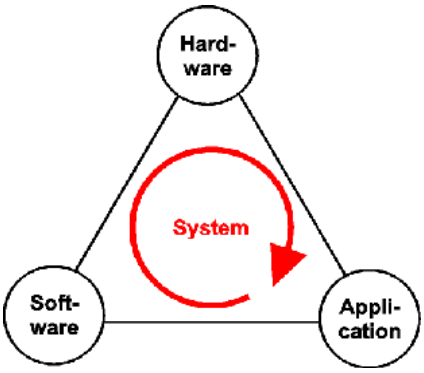
Living Labs is a concept claimed to originate from Prof William Mitchell, MIT, which in this context refers to a lab with user-needs-driven development. In the Swedish context, it is an initiative designed to combat the high rate of failure among new IT-projects. This study of the t2i lab ties in closely to its definition as a Living Lab, and thus the focus on its context; how a small research lab fits into the community and exchanges ideas and inspiration with it. A Living Lab must also have a stable foundation in the various communities that surround it, and have equally solid project plans for future development.

This is a relevant part of the project background, because the Living Labs concept to a large degree is allowed to dictate the definition of which direction it is desirable to develop the lab towards; a set of standards to aspire to follow. The methodology in itself provide the analytical tools to find the current state and work from it, while the Living Labs definition provides the end point, or goal.

## OTHER TANGIBLE INTERACTION LABS

The Innovation Center Virtual Reality (ICVR) is another small research lab connected to ETH, Zürich, which researches and implements Virtual Reality applications. As it cooperates with the t2i lab, it is perhaps not surprising that they share several characteristics. The ICVR focuses on cooperation with the academic world represented by the close at hand ETH and the commercial world through the company inspire. In other words, it shares several of the characteristics of a Living Lab.

For this study, it is mostly a background "font", if you will. While it would have been very interesting to analyze another lab according to the same principles as the t2i lab, that was impractical for a master's thesis. However, because of its cooperation with the t2i lab, it remains especially significant.




**Picture 8: The ICVR corner stones of Virtual Reality Systems.**

# METHODOLOGY

An important part of this project is to establish a working methodology, since this kind of analysis is somewhat unknown territory. Because of this, a set of known methods are taken and adapted to a purpose. Below will be included not only the theories itself, but their practical uses. Because of this, each method is divided in a "method description" and a "method adaption" section. The method description section deals with the theory as is presented in literature, and method adaption describes how the method was adapted to suit the project's purposes.

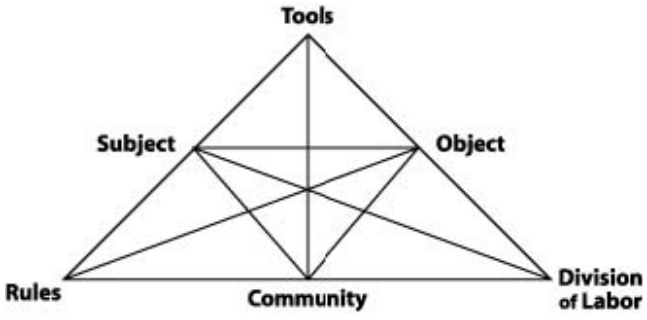
## ACTIVITY THEORY

### METHOD DESCRIPTION

Activity theory aims at understanding and explaining human behaviour from a cognitive perspective, as well as understanding that human behaviour cannot be isolated to a single human, but they rather work in consort. The centreline unit of information is the defining term "Activity", which I exemplify with the grammatical definition: an object performing an activity on a subject. For definition purposes, it is also important to notice that the activity needs to be motivated (Nardi,1997), or it will remain nonsensical. While that may seem natural in activity theory, the definitions may conflict when it comes to non-sentient activity, for instance volcanic activity, where motivations are scarce. It should not be confused that these deal with completely different matters.

Activity theory originated in the Soviet Union during the Cold War and is attributed to Leontev, Luria and Vygotsky. These three created the foundation of Activity theory, which was at the time an important discipline of psychology, and had very practical applications in Soviet. Much later, in the 80s, Activity theory was taken up as research in Scandinavia by Engeström and later in the United Kingdom and USA, much thanks to the efforts of Bonnie Nardi.

There is some debate whether or not Activity theory is a descriptive tool or a predictive tool, but I will not make a sharp distinction between the two and take the middle road that the two are not mutually exclusive, and leave the conclusions of whether or not one or the other of these two applications are more powerful than the other. More matter of fact, Activity theory can be used to structure a model describing the workings of the human mind in a context, and from this structure conclusions may be drawn according to a suitable theory.




**Picture 9: This is the activity theory triangle, used to describe how the different parts of activity theory, and how they relate to each other.**

These parts of activity theory are intricate, but fairly well defined:

- Rules: These are simply the rules which apply to the subjects within communities
- Subject: This is an entity taking an active part in the activity; group, person, but not object (as per definition)
- Tools: These are methods, or actual tools, with which the Subject work towards the Object.
- Object: This is the goal of the activity
- Community: The social surroundings of the activity, a group of some or all involved Subjects
- Division of Labor: The manner in which the activities are divided among the involved Communities.

This would require some further explanation of the system of these parts. The triangle in Picture 9 is in itself divided into multiple sub-categories. Think of a simplified triangle with only Subject, Object and Community, where a Subject works on an Object in a Community, a context. Add to this tools which affect how the Subject interacts with the Object, Rules which affect Subjects within certain Communities, and finally Division of Labor, which affects how the community works towards the Object.

When broken down like this, the complexity of an Activity can be described, categorized and analysed. It is still not quantitative, but the quality can be compared with other options. This leads to another interesting aspect – that that you can study the change of an activity as parts of it changes, and vice versa.

### METHOD ADAPTION

The adaption of Activity Theory becomes useful in this project by looking at the change. The theory itself provides a framework for description, but adapting it to look at changes from one state to another serves as comparison, in this case to an "example laboratory" with generic properties, and this project looks at these differences in order to categorize a few of the properties attributed to the t2i lab, and can be used in a similar way in any such situation.

Activity theory here concerns the structure of how the people at the t2i lab assess information and work with it. Perhaps it will become quite important to see which of the activity theory components become particularly different from a more common research environment.

The basic idea is to study the lab as an "entity" and the people as user with projects as "tools", for using Activity theory nomenclature. With this adaption, the question is: what can be said about the environment as a whole, and what kind of activity theory descriptions can be assumed to be useful in a comparison?

## INTERVIEWS – EXTERNAL ASSESSMENT

### METHOD DESCRIPTION

The core objective of this method is to find information which is easiest accessible directly from a person. This concept is described in detail in several books, with regard to HCI, where some are more general and others more in-depth. The most interesting one is more specific, as it focuses on interviewing only users of a system (Jones, 1992). While this is not strictly the case, it contains several benefits over the more general methods described for instance in (Dix et al, 2004) which proposes a more rigid and less in-depth structure to the interview. Because of this, the method as is explained here might seem a curious choice, but this will be explained in the adaption.

These are the proceedings of an interview, according to (Jones, 1992):

1. The first and most pivotal part of the interview is to identify which user situations which are relevant for the situation at hand.
2. After this, it is most important to get those who could be affected by the interviews or a possible changed system to agree to the interview taking place. It is important that the information to be gathered is as neutral as possible.
3. The users must then be encouraged freely to give or show how their activities take place in the situation which is to be studied.
4. During this conversation, it is the job of the interviewer to focus the discussion on the parts which are important to the evaluation in a graceful way so as to not break the confidence of the interview.
5. The information gathered from the interview should be recorded as soon as possible, during the interview or just after, even if it seems only a little important.
6. If possible and deemed appropriate, get the interviewed user to review the conclusions drawn from an interview.

There are some interesting things to note about these points of interest, specifically as to what actually constitutes an interview. Another point of interest is what kind of hidden information is accessible through the use of unstructured interviews, as opposed to structured interviews. Note that Jones method, though not specifically stated, leans towards suggesting that the Unstructured Interview is commonly more useful when it comes to situations where even some of the relevant information is assumed to be hidden. Jones would probably consider unstructured interviews the default approach, with structured interviews being the special case which is appropriate only when you are confident that you know which information is relevant.

As for what constitutes an interview, it is easy enough to integrate additional information gathering into the actual interview; observing user behaviour (Jones, 1992). In point three in the list it is stated that it is important to encourage the users to not only describe but also to demonstrate the important parts of the studied activity. Basically this means that it is important to find hidden, "wordless" information. When the purpose of information gathering is to get a general orientation rather than the answer to a direct question, complementing the answers and descriptions with an actual demonstration is an obvious advantage. This complementary method also decreases difficulties in communication, if the interviewer isn't sure of whether or not the interviewees will answer the questions completely according to their purpose.

**Picture 10: A good interview should be both well planned and reasonably relaxed.**

## METHOD ADAPTION

Quite early in the project, it was made clear that there would be two different kinds of interview which would dominate the project, both with similar purpose but with different opportunities, and thus somewhat different methods.

A number of in-depth interviews were carried out with potential customers of already perceived development areas for the ForceFeedback Slider. The main purpose of these interviews, which were unstructured, was to glean visions of how an end-user would like to work, ideally, as well as if and how the ForceFeedback Slider could help in achieving these goals. Because of this, the nature of the interviews were strictly informal, and as natural as possible an environment was encouraged for observation. As is specified above, there is a lot of information to be gathered simply by setting the interviewees free to demonstrate what is important to them, and to learn that. After that it is only natural to guide the interviewees to specific areas of interest.

In a sense, it could be argued that this, then, was formally semi-structured interviews, but I don't believe that to be the case. The difference would be with which intent guidance is applied. The semi-structured version would apply the same kind of control, but the purpose would be known from the start. As opposed to this, the unstructured interview still lets the interviewer guide the interviewee through the process, but not to any predefined questions which need answering, rather to points of interest rising throughout the interview. Keeping a general purpose in mind is, in the end, quite different from having several specific purposes to consider.

Another part of the interviews was the more informal ones, which were still carried out in a semi-structured manner, during Morten Fjeld's client meetings, which I attended. The actual purpose of these were to establish common ground for research and or commercial cooperation, and took place with a number of different companies. As I attended these meetings, I had the unofficial role of providing alternative perspectives as well as analyzing the value of the common ground which was presented at these meetings. These meetings take the form of an elaborate metaphorical handshake, where both parts share information in order to find a basis for the discussion, which in itself is nothing out of the ordinary, but an observation to explain why this provides fruitful information.

# EXPERT EVALUATION

## METHOD DESCRIPTION

The core of expert evaluation is a data-gathering technique same as many others, but is easily compared to similar methods in that it takes much less time and effort while it is definitely more arbitrary because of the uniformity of errors that will occur once the evaluator group grows small. Because of this lack of certainty, Expert Evaluation is not very often included in the method toolsets and literature on the subject is harder to find. In contrast to this there are some studies that have concluded that Expert Evaluation as a method can be very useful under the right circumstances (Karoulis et al., 2006).

The basic concept of Expert Evaluation is that an expert can review a product or project according to direction, and answer the same questions that would be posed by an interview or a questionnaire. While the expert is just one person, or a small group, it is considered that they find points of interest faster and that their comments are more relevant, effectively substituting a larger population for a much smaller while retaining the same amount of useful input.

Being far from adequately described, I'll attempt to formalize Expert Evaluation as though I think it should be used in a project:

1. Identify the requirements for what constitutes an expert at the task at hand
2. Evaluate your candidates on the basis of this specification, and whether or not you can achieve a fair review of the situation with them.
3. Make sure the experts understand what is expected of them, in a delicate way, since parts of what is evaluated might seem trivial or irrelevant to them.
4. Allow the experts a significant portion of time to exercise their judgement; be patient
5. Observe the evaluation process, if possible, for nonverbal conclusions and variants not put down in notes.
6. If appropriate, allow the experts to comment on your notes and conclusions.

Once this is done the conclusions can be weighed in towards a final opinion, but it should be noted that while the information input probably have a high relevance, the confidence for its correctness is lower than with other information gathering techniques and that it should not be used lightly to argument for changes with a large impact.

### METHOD ADAPTION

Several of the decisions in the project were not explicitly based on the here mentioned methods, but were the results of judgment calls based on earlier experience. This is called the expert evaluation method, the use of which should be carefully considered, because of the lack of causality and repeatability. The method has its uses, though, especially for situations that fall in between other methods, or are too trivial to spend much time on. It is respectably used whenever it can safely be assumed there is a consensus on the topic. In a sense, it is more effective to discuss when to use expert evaluation on a case by case basis than as a general rule. In these cases, the method serves in a complementary fashion to the other methods.

The method was not quite used as is formalized above, largely due to the fact that I was not very skilled at methodology at the time the project was carried out. The actual proceeding was roughly similar, but followed more along the lines of User Observation, as is detailed in the Interview Section above. It should also be attributed to this method, perhaps, the large number of personal judgement calls made throughout the project, and especially so in certain situations.

For instance, in a lot of the project work involved, it was common with "handshake" meetings; with the strict purpose of evaluating possibilities of cooperation. While this is formally a sort of brainstorm, Expert Evaluation fills a valuable role in facilitating quick reactions to the commonly occurring loose ideas during this kind of meeting. Again, while this is an informal application of the method, my conclusion about its usage is that it is best saved for ad hoc solutions as an auxiliary method.

## RELATED PROJECTS

### METHOD DESCRIPTION

What I call Related Projects is more or less an adaption of traditional Literature Search. The formalized adaption is based on the difference where traditionally information is already available, as opposed to actively working towards promoting the review work at hand. Another difference is that I usually took part in the work, in some aspect. However, as these are extensive sources of background material in their own right and my contributions were distinctly small, I believe it is best to post these as formal Literature Search with these few caveats.

The method is well described (Jones, 1992), like this:"

1. Identify the purposes for which published information is being sought
2. Identify the kinds of publication that are likely to contain information that can be relied upon for such purposes.
3. Select the most relevant of the standard methods of beginning a literature search.
4. Minimise the search cost by allowing for retrieval delays and by continuously evaluating both the choice of sources and the applicability of data collected.
5. Keep accurate and complete references to documents that are found to be usable.
6. Keep local collections of publications sufficiently small and temporary to permit rapid retrieval."

This approach basically means to not only have a clear purpose but also to retain the causality chain, so that all information of how and why is kept scientific. This is surprisingly uncommon in information gathering processes, and would in many cases need attention in keeping with a proper log.

## METHOD ADAPTION

During the course of this thesis project, a number of other people provided valuable information through other projects, often in cooperation with myself. These projects are in their own right, but for my purpose, they serve as to provide relevant information, each with their own method (Jones,1992). This includes an investigation which analyzes the intellectual property situation of the ForceFeedback Slider as well as the Research on the slider itself. Notable is that the causality was lost due to not keeping a log. This unfortunate consequence will be discussed below, in "Conclusions".

# RESULTS

## END USER INTERVIEWS

All of the end user interview material is given in the form of the contracted notes from the interview in question. Since the interviews were only very weakly structured, the results are given as these interview summaries instead. It should perhaps be noted that while there are some reflections in the interviews themselves, these are a natural part of the interviews rather than actual analysis of the material applied afterwards. Keeping that in mind, the analysis should be considered mutual, as it is the result of an open-ended discussion between the author and the interviewee. This initial analysis will also be subject to further discussion and analysis in the Conclusions section below.

### DANIEL WESTERBERG, SR

Daniel Westerberg is a professional DJ at Sveriges Radio, SR, and this interview helps provide insight in how a DJ would benefit from technical improvements to his working environment.

Everyday use of the machines in question is, largely as expected, both quite repetitive and uncomplicated, even if there are great opportunities to complicate them. The systems used at SR are of the brand Mandozzi and are manufactured in Switzerland. They let the user log into a computer system which is intimately connected to the digital mixer and the control box (all in one) and access their own private settings and quickly start the work with a minimum of settings changed. A thought is to maybe become inspired by this and create some kind of support for individualization.

An interesting thought which arises in connection to so called intelligent support is where the border is between control, assistance, freedom and flexibility. From an outsider and a non-user's perspective was SR's system very rigorously tied up; it communicated in fixed, well defined ways and provided lots of support for performing similar tasks in the same way. For example, starting jingles with one press of a button while shows were "fed" thanks to a pre-planned schedule on the computer. The usage of these is considered if not intuitive then easy to understand and once you have gotten used to it quite comfortable to use. This runs in contrary to a quick visual inspection of the controls, which can be assumed were not designed with ease of use in mind, and at a first glance remind of the panels of old which required engineers to understand.

**Picture 11: The ForceFeedback Slider has a natural potential for being used in music applications.**

Without going further into the different functions which a mixing table has it is mostly about managing the volume of different channels in the right time for different jingles, show features or changes of shows. The sliders are already motorized, and can be turned "on" which means they are gradually brought to full volume, even all the physical sliders for each channel. This process is quick, but not immediate.

Other ideas which were not approached more carefully is to have a warning in the slider when you i.e. work with it as a certain function, perhaps as a compressor, and approach a "red zone" (this comes from the graphic equalizers, meaning that the channel is considered to be too loud). You could also use them to keep in the prioritized states in a similar way, and give physical warnings there which become stronger the further you deviate from the state in question.

## CARL DAHLBERG, PROFESSIONAL MIXER

“Trash-mixing” (“Slaskmixning”) is a concept term for the very first, beginning mixing when the channels are set very roughly in order to have a basis to work with. It is usually made in a matter of minutes, listening roughly by heart. Later on, the graphic equalizers find their use, and progress is made. The first impressions are then fine tuned in the mixing process in its entirety, using both graphical equalizers and listening as practical feedback. A ForceFeedback Slider can be very useful here, we agree, by providing tactile stimulation for trash-mixing with predefined rulesets.

Basic mixing (Grundmixning) is another situation where the slider could be useful. A basic mixing is a template which is created to be a crude channel volume setup which roughly fits the most common applications. This kind of basic mixing is often useful with similar projects, and should be considered a common application, very similar to and perhaps exchangeable with the “trash-mixing”, which is a more one-time version of the basic mixing. A common problem here is that the master volume will end up being about 10dB too high once the other channels are at a fitting level. This means you will have to start over once again, and the ForceFeedback Slider could potentially give feedback also on this, alternatively be used to correct other channels when the master volume channel is decreased.

Regarding visions for the future – today there are many diagnostic tools for sound landscapes which points out deviations which are percieved to be negative. Unfortunately they do not meet the requirements, either on account of being too slow, or they are not precise enough and do not give a credible view of the problems at hand; because of these reasons they are rarely used. Commonly, the feedback from these diagnostic tools are represented as equalizer graphs on a computer screen, and lag behind the actual rhythm, and is not considered credible.

Possibly this can be combined with Force Feedback to give a real time diagnostic feedback directly to the slider, but this must be able to be individualized to a high degree to be of any use to a professional user. But the thought remains and can be developed further.

## DAVID CRAFT, MULTIPARAMETER OPTIMIZATION

<This has been omitted for confidentiality reasons>

## NOTES ON CLIENT/RESEARCHER MEETINGS

These meetings were an important contributing factor to gaining an understanding for how the t2i lab worked in relation to its community – the outside world of fellow researchers and commercial companies interested in the research. In order to find information about this facet of the lab, a number of meetings with potential clients, partners and researchers were conducted where I got to attend and gather information for the project.

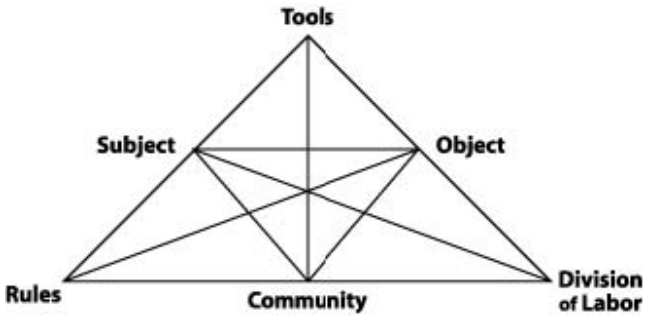
The sum of the results of these meetings, though, were not tangible in the sense of “golden words” that were needed to be written down, but were rather corroborating a set of fairly non-specific conclusions. One strong impression from the meetings is that there are several overlapping fields of research in the general area. This is notable only because perhaps tangible user interaction is not a matured business area, which leaves both the intellectual property and other commercial aspects insufficiently explored. In other words, there is a lot of research on potential levels, without established standards.

There are several patents, though, the market isn’t quite open, which in turn means that there should be lots of opportunities for cooperation and incorporation of ideas among interested parties. This is the geist of these meetings, that the current situation corresponds to “a land of possibilities” where there are lots of ideas and

semi-matured projects. In turn, this of course opens up for many synergies as well as powerful pushes towards “silver bullets” of the discipline.

For a small research lab like the t2i lab, this means its situation is far from unique, as far as project maturity goes, even though its academic situation is somewhat unique and provides benefits as far as cooperation goes, something which it seems would be appreciated. The number of existing and newly formed cooperations the t2i lab has formed to businesses and other research labs, such as the one at ETH, Zürich, would indicate that this is true, as well, and also that the market is as open as could be supposed.

Cautiously summing up this information, then, means two important things: the market for tangible interaction is both open and insecure. The way lies ahead, but is not yet paved.




Picture 12: The Activity Theory triangle with which the labs have been cathegorized.

Modelling the T2i lab according to Activity theory only clarifies a structure which is already there, which is important to bear in mind considering this analysis. The important part will be to see how the "lower right triangle" develops; the relation between Object, Community and Division of Labor. But first let's see how the components are represented in the T2i lab:

| Component | T2i Representation |
|---|---|
| **Subject** | This is most often a student, working either on a Bachelor's or Master's thesis or another similar kind of project. In some cases, there are exceptions like project employees or other CTH researchers. |
| **Object** | The object is one of the projects which fall into the T2i sphere of interest, either one from the distinct list mentioned above or a novel idea deemed to fall into this sphere of interest, and is compliant with the required academic level. |
| **Community** | The whole of the T2i lab is represented in the Community, contextual concept, the people as a group along with the physical locale. |
| **Rules** | The rules of conduct governing the conduct while performing an Activity, that is working in the lab, are quite straight-forward, although not formalized. Keep in mind that they are focused on the way the Subject interacts with the Community. This is kept as a both ways bond with regular supervision meetings, but also tune-up meetings with co-workers working on similar projects, seminars as well as extra-curricular activities.<br>An exhaustive list would probably cause the scope of detail to be left out, so this description focuses on the core elements. The term rules, in this sense, is somewhat less than precise when dealing with people, and in this context should be seen more as "conditions" |
| **Tools** | The opportunities for which the lab member has to achieve their objective is here called Tools. These tools include computers, electronic construction kits, literature, working space and a budget of varying size. |
| **Division of Labor** | How is the community context helping in achieving the objective? The T2i lab gather several people of varying expertise and field of interest, but in itself forms a grid of contacts. It is easy as well as common to find synergies between two Subjects' Objects and a certain distribution of labour becomes not only common but also expected. |

And this might be how a standardized student research environment would be on CTH. While this ofcourse varies greatly, a "barebone" representation is used. This is not a fair comparison, nor meant to be, but should be seen as a benchmark to observe changes against:

| Component | Standardized Representation |
|---|---|
| **Subject** | A student working on a Bachelor's or Master's Thesis |
| **Object** | The objective is compliant with the academic level of the thesis, and can be directed towards any research area. |
| **Community** | This is heavily subject to circumstance. However, two general options apply. Either the |

| | |
|---|---|
| | Subject works on his own, towards a supervisor, or the student is embedded in a normal workplace environment. The latter would typically mean working in a team of significantly more senior co-workers. |
| **Rules** | If the Community is nonexistant, the Rules-Set is empty as well. Likewise, for a circumstancial Community the Rules will be correspond. However, given the assumption of working among more senior workers, rules of conduct will typically be the Subject is in the role of performing a task not appointed to a more senior member, and will likely serve to establish the Junior-Senior perspective to the Rules. This does not breed the same kind of creative synergies as working with your equals does. |
| **Tools** | Typically what physical equipment is necessary for the task, and a computer to document, organize and report, even if not strictly necessary for the task. The university will provide its normal resources, including group and public rooms, the library and additional computers. |
| **Division of Labor** | Again, No Community means no Divison of Labor. The likely alternative as proposed above means a situation where synergies and cooperations are still quite few, and where the work towards the Object is isolated. |

While all this is categorized, the purpose to adding the "benchmark" evaluation is to allow for a comparison, which can give information about what kind of characteristics are particular to the T2i lab environment:

| Component | Transformation properties |
|---|---|
| **Subject** | The subject remains essentially the same. What little variation there might be is only included for completeness. Essentially, the subject functions in the same capacity regardless of which of the two activities is considered. |
| **Object** | Same as the Subject; the Object remains similar in order to be relevant. For the comparison to be relevant, we should be looking at similar people performing similar tasks. That the two sets can entail different people is a valuable property of each, but strictly for comparation purposes it is more useful to look at manipulateable circumstances. |
| **Community** | The changes in community is the basis for this comparison. We have the T2i lab, as is described above, and on the other hand a font of co-workers. It is worth noting, though, that it is quite probable that the T2i lab has a far younger community, with less established traditions. |
| **Rules** | The prime change in the Rules-set is that of equal footing. Working in an area dominated by students eliminates most if not all formal constraints on hierarchy, and allows much for freedom when it comes to interacting with the |
| **Tools** | It should be safe to assume that the Tools needed to complete the task should be available in both circumstances. Possibly they are a bit closer at hand, physically, at the T2i lab. |
| **Division of Labor** | It is reasonable to assume that through being a more integral part in the Community, any Division of Labor steps will be easier to facilitate, and because of this infrastructure, we'll see a more distributed workload. Through working more closely together there are many side-benefits such as second opinions, automatic input of auxiliary knowledge and opportunities for a more flexible schedule (examplified with two people working on the same project for a while, under a period of time constraint). |

As is seen in the table above, there is, as expected, several differences between the T2i lab environment, and a generic environment simply because of structural changes in the organization. A simple analysis of an Activity, in this case, serves to provide rational arguments for structures otherwise too simple to describe, perhaps even notice.

## INTELLECTUAL PROPERTY REPORT

Students at the Center of Intellectual Property Studies have completed a study of a particular use of the Force Feedback Slider. Part of the project was to encourage and guide these students as they were working on their project, and afterwards to review the impact of the report. This was mostly completed without formal methodology, but in itself provided important results to evaluating both the T2i lab and the ForceFeedback Slider in particular. No further analysis of the results is given here; the report as was accepted contains all the information (Blomgren et al, 2007).

## THE CONTINUOUS FEEDBACK

Throughout the very long span of this project, much of the work relied on momentary feedback. For instance, the client/research meetings would have been useless without the immediate analysis and resulting feedback. However, the thesis project itself requires a lot more afterthought in certain matters, as well as analysis on a larger scale and time frame analyses. In spite of that, and the length of description given here, the continuous feedback has perhaps been among the most important parts of the results of this project. In truth, this was unforeseen to start with, and lacks documentation. The lesson learned, there, is to make note even of such. As it is, all of the results and conclusions in this report have been a part of the continuous feedback, but keeping with a project log will make record of progress in its smaller stages.

# CONCLUSIONS

## TANGIBLE CONCLUSIONS

### CONCLUSIONS FOR THE LAB:

As can be seen, the T2i lab is a vibrant community. Of this there was no doubt before, but a more formal conclusion is in order. After analysing the lab and its projects with activity theory, this produced some thoughts and conclusions about it. One of these is that the strength of the T2i lab as an organization and a research unit is built on the synergies and casual research environment which is created there. In short, gathering students in one place is a good move for increasing not only creativity, but also the quality of the result from their work. Enforcing a community does not only, as is naturally assumed, make the T2i lab a more fun to work at, but also produce more tangible benefits.

In order to work on this and augment these strengths, the bonds between projects and co-workers can be further investigated and strengthened so that the research output in turn becomes more reliable and manageable. These conclusions should be intuitively known to most experienced managers, but there is no current practice for creating such a baseline environment for thesis workers, as these are indeed treated mostly like traditional apprentices rather as parts of a normal workplace, which is most likely already planned around these principles in order to increase productivity.

Another area which is readily possible to strengthen is the projects and their definitions. The research and client meetings along with the interviews, as well as undocumented evaluation have revealed that the projects in their current state sometimes lack a well communicated focus, if there is a well defined one to begin with. The T2i lab is in itself an environment which does not conserve knowledge through longstanding workers, with the recent exception of a PhD student, but rather through a continuity in the projects which is directly connected to Morten Fjeld, and students which begin projects at the T2i lab do not always get to absorb the bulk of the knowledge built up in the project.

This lack of continuity is a property which is hard to build away with the current resources, but structural changes to the ways projects are given and started might address the problem. By stating more long term goals with scientific or intellectual property parameters, the chain of causality which is acquired will be both more productive as far as building up a strong intellectual foundation goes as it is with regards to continuity and attainability for attaching new projects to the “lore”. This will both differentiate them and strengthen their profiles.

### CONCLUSIONS FOR THE PROJECTS:

More specifically, the projects themselves have also been shed some additional light on. The ForceFeedback Slider was an early focus of the project, and was the focus of the main interviews that were conducted during the course of the project. Some of these arguments were direct than others, and some offered circumstantial value rather than more well defined content. However, it was without a doubt noted that there are several potential research areas which might lead to commercially viable products, but projects directed towards invention height will strengthen the chances of solidifying intellectual property rights concerning these products.

Especially for the ForceFeedback Slider, this holds true, but there is no reason to believe other than that this holds true for other tangible products. As is evident from the interviews, it is in several areas easy to think of opportunities in which tangible interaction might well become an advantage, with both production and control

of music as well as medicine as very real examples. These are, though, simply a few of many suggestions, which should be noted, and the real lesson is learned from the intellectual Property report (Blomgren et al, 2007).

The ForceFeedback Slider is a relatively old project, and is definitely to be considered mature. Further development inevitably concerns perfection and/or application, at this stage, and the problem of intellectual property became acute quite soon after these possible projects were considered. The report then provided the necessary insight to realize what is a concern for any mature project in this situation; that of focus and direction. The current, genetic development of the projects has not supported these attributes, but instead faces the dilemmas created by neglecting them more severely this advanced in the project lifetime.

To focus the development is naturally not necessary for all projects, neither should all research be implementation directed at its first stages, but every now and then a survey can catch up and evaluate the status of the current projects, both with regards to innovative height and implementation focus. This also directly affects and helps the students, since it provides an easy approach to clear and meaningful projects, and should be advised for all projects some time into their lifetime. Over all, Tangible Interaction devices have a strong technical potential, as they provide additional information to and from old systems, instead of the more traditional one-way relationship.

## CREATING A BASELINE FOR THE DIFFERENT PROJECTS

This methodology can be adapted and used in a similar manner for the various other projects in the t2i lab. Doing so should be a priority especially for the more matured projects, which need focus as well as recognition. Providing purpose and a foundation for the projects in general should be considered a beneficial thing, and ties in the projects to active veneers. A living lab has a beneficial effect not only on plant school projects, but also in bringing continuity to more matured projects that need purpose and application rather than to support a useful principle.

## TIMELINE, PROJECT PLAN AND USEFULNESS

As the scope of this project has changed over time, it quickly made the existing project plan completely useless. With the project plan went the timeline it depended on. This was a relevant change of the project, which in essence changed its direction from outwards to inwards. From how the slider could affect the world outside the lab, to how the lab was affected by the slider, in essence, as this remained the starting point. The general purpose remained the same, though: to find suitable “directions” for the t2i lab in its future development.

The change itself was brought on when methodology came into the picture, as well as preliminary information gathering. Bringing this new information to the original vision meant that the priorities needed to be revised, or more plainly that it was far more useful to examine the lab itself with the tools at hand than a specific application, given the range of possible results.

The alternative approach to that would have been to narrow the project down and adapt the tools instead of shifting the scope. However, it was deemed much more useful to investigate the lab itself than the slider alone, and give a wider range of practical results. Introducing a change of scope, though, did as mentioned upset the project plan to the point of scrapping. The new timeline was created with a surplus of time in mind, as well as the need to observe the lab over an extended period of time.

That is the main reason why this project took so much time, eventually, that the data gathered for the new scope required so much more time. In the end, though, I believe this was well worth the extra time and effort, as interesting methods yielded interesting results.

## FUTURE WORK

Even though this project spanned a very long period of time, there is always work left outside the scope. The most important future work would be to do a second iteration and test the methods after development, and modify them as necessity dictates. Furthermore, expanding the research to cover the academic context properly is an important step for finding the right priorities, which unfortunately had to be cut out because of time constraints. Finally, it would be very interesting to see how a more thorough adaptation of activity theory would affect the results, as the one used here only uses the basics, not to mention that it is unorthodox. In short, what this project needs the most is validation, in order to create a dependable set of method.

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## CREDITS

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# APPENDICES

## ORIGINAL PROJECT PLAN

(In Swedish)

Fas ett, juni till mitten av september

Här är huvudsaken att undersöka möjligheterna, och bör kulminera i detta dokuments slutliga representation: en projektplan.

Hitintills verkar det finnas två uppenbara möjligheter, där en verkar mer produktknuten än den andra, på gott och ont. I och med att den huvudsakliga undersökningen är inriktad på en förbättring av användarinterfacet för slidern så kan fokusering mot en speciell produkt betraktas som ett specialfall snarare än en förbättring. Å andra sidan har en tillämpning av slidern klara positiva drag.

Avslutas med en färdig projektplan

Fas två, mitten av september till slutet av oktober

En undersökning för att se hur, mer specifikt, utvecklingen skall gå till, vilka områden som är att anses fruktbara för utveckling och därtill den grundforskning som behövs för att starta den iterativa utvecklingen i nästa fas.

Avslutas med en detaljplan för fas tre, produktutvecklingen

Fas tre, november månad

Utveckling av den valda produkten i två till fyra iterativa steg, med undersökningar och feedback emellan varje.

Avslutas med en i största görliga mån färdig produkt

Fas fyra, december månad

Rapportskrivning och analys av arbetet samt produkten. En grundlig genomgång och revision av projektet och produkten, samt författandet av den slutgiltiga rapport som sedermera skall lämnas in för att räknas mot examensarbetet.

Avslutas med en färdig rapport

Fas fem, någon gång under januari månad

Muntlig presentation och opposition av examensarbetet, som i mån av möjlighet kommer att hållas någon gång under januari, när de flesta övriga formaliteter är avslutade.

Avslutas när presentationen är hållen.