SQUATOUCH

Object Oriented Sounds / Tangible Musical Interface

by
S. ALP TUĞAN

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ABSTRACT

SQUATOUCH
Object Oriented Sounds / Tangible Musical Interface

S. Alp Tuğan

M.A., Visual Arts and Visual Communication Design
Thesis Advisor: Hüseyin Selçuk Artut
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This article investigates the theoretical and the practical terms in the formation of *Squatouch,* which is a computer-based musical interface and offers a multitouch user interface via the forms of direct interaction.

Multi-disciplinary structure, named as Interaction Design today, carries the communication methods with computers to a different level day by day. Initially based on only mouse and keyboard interaction and single-user oriented interaction paradigms, it now provides multi-user oriented alternative interaction methods thanks to the rapid improvements in technology. However, the technology providing the user those opportunities expects the user to learn a new language. Multitouch interfaces are among these new languages through which more than one user can interact directly by using their hands without a mouse or a keyboard.

In that context, the following article presents *Squatouch*, which carries the human-computer interaction to a higher level by providing a tangible interface that is alternative to traditional graphical user interface.

Keywords: interaction, interface, language, multitouch, Squatouch, technology

ÖZET

SQUATOUCH

Obje Yönelimli Sesler / Dokunulabilir Müzik Arayüzü

S. Alp Tuğan

Y.L., Görsel Sanatlar ve Görsel İletişim Tasarımı

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Bu makale, bilgisayar tabanlı müziksel bir arayüzün, doğrudan etkileşim yollarıyla da kullanılabilmesi için, çoklu dokunulabilir kullanıcı arayüzü öneren, *Squatouch*'ın, oluşumunu etkileyen kuramsal ve pratik koşulları incelemektedir.

Günümüzde etkileşim tasarımı olarak adlandırlan multi-disipliner yapı, bilgisayarlar ile olan iletişim yöntemlerini her geçen gün farklı bir noktaya taşımaktadır. Önceleri sadece mouse ve klavye etkileşimi baz alınarak kurulan, tek bir kullanıcı odaklı, etkileşim paradigmaları, teknoloji sayesinde artık çok kullanıcı odaklı alternatif etkileşim yöntemleri sunmaktadır. Ancak, bu imkanı sunan teknoloji aynı zamanda bizden bu imkanı kullanabilmemiz için yeni bir dil öğrenmemizi beklemektedir. Birden fazla kullanıcının aynı anda, mouse ya da klavyeye ihtiyaç duymadan, ellerini kullanarak doğrudan etkileşebilecekleri multitouch arayüzleri de bunlardan biridir.

Bu bağlamda, bu çalışma, geleneksel grafik arayüz sistemine alternatif olarak dokunulabilir arayüz sistemini sunarak, bilgisayarlar ile aramızdaki etkileşimi bir üst noktaya taşımayı önermektedir.

Anahtar Kelimeler: arayüz, çoklu dokunma, etkileşim, lisan, Squatouch, teknoloji

TABLE OF CONTENTS

LIST OF FIGURES

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INTRODUCTION

"Oh, how would you control a cursor in different ways?" (Worthey)

This paper contains on information and on assessments of *Squatouch: Object Oriented Sounds/Tangible Musical Interface*, which is formed as a part of my master's thesis. *Squatouch* is a tangible user interface that allows for producing, mixing and processing sound. By introducing a tangible interface, it proposes an alternative interaction method for sound production instead of the classical method consisting of computer-mouse-keyboard interaction between the user and the computer.

Before computer technology entered everyday life, interactions with the machines were made by direct physical contacts. With the invention of the mouse and the increase of the personal computers (PC) usage in the 1960s, interaction methods have changed considerably. Many physical platforms such as the documents and notes that were kept in notebooks, calculators, photograph albums, and the control interfaces of the mechanic machinery started to transmit to the computers by being converted into visual interfaces. The interactions that were used to employ using our hands and physical interfaces, revolved into the point of a mouse. This new method of interaction enabled the user to control everything from a single point, because the computer mouse was designed as a multi-functional control interface.

Today, a few decades after the invention of the mouse, methods of interaction have once more started to be reshaped. The concept of the Tangible User Interface makes it possible to produce alternative solutions to the WIMP[1] interface system. One of the new alternatives, multi-touch screens, are being widely used nowadays. Multi-touch Screens allow the user the possibility of controlling the interface using their hands as they did in the past. Therefore, the interfaces of the software developed for the multi-touch screens are of vital importance. However, even though the interaction methods are made easier, inconvenient software applications made the interfaces impracticable. Hence, the user interfaces become the key points in interface design.

[1] WIMP: "Windows, icons, mouse and pull-down menus, alternatively referred to as windows, icons, menus and pointers." (Preece, et al., 2002 s. 60). WIMP term is generally used to tell interfaces which are based on mouse and keyboard interaction.

Nowadays, there are several types of available applications developed for multi-touch interfaces, such as photograph album applications (Recollectable)[2], interactive interfaces designed for kids (Mü)[3], and game applications. However, there are few interfaces developed on sound editing and synthesizing. Squatouch is a sound generator and synthesizer interface developed for multi-touch screens. There are various software programs on sound available today; however, most are developed on mouse and keyboard interactions. Interfaces developed on the basis of traditional interaction paradigms do not give the necessary utilization needed and therefore cannot be functional for the users. Although computer keyboards are suitable digital tools for writing, it is very laborious to use them as musical instruments, and thus external control interfaces are developed for computer- based sound processing software such as Midi Controllers. However, it cannot be said that these solutions have taken the human-computer interaction to a new level, since the interfaces still require the mouse and keyboard.

The first chapter of this thesis provides general information on Interaction Design that emerged within technological innovations. Then, there is an introduction to the relationship between society and technology, because the designer develops the communication language according to this relationship.

In the second chapter, development of computer technology that became a part of our daily lives and the factors, which affecting these innovations, are discussed. Furthermore, social determinism and technical determinism, which have been the two main theories, suggested in order to explain societal and technical changes are cited.

In the third chapter, there is a discussion and an assessment of sound studies, the relationship between sound and technology, and new musical interfaces.

The final chapter covers theoretical and practical information about *Squatouch: Object Oriented Sounds/Tangible Musical Interface*, which is developed as a part of my thesis. Moreover, the section on Technical Design and the developed interaction/communication language were documented comprehensively in terms of

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[2] Recollectable: A master thesis project from IT University Copenhagen, Denmark - http://www.rasimu.dk/thesis (accessed: June 20, 2009)

[3] Mü: "MÜ is a multimedia installation featuring children fairy tales. MÜ is intended for infant schools (5 – 6 years old children). The educational purpose of MÜ is the early learning of hearing, musical and creation, through activities that can be played alone or in group." http://www.mu-project.com/ (accessed: June 20, 2009)

providing information on multi-touch screens and applications for other designers those who plan to work on these subjects.

CHAPTER 1
Interaction Design

1.1 Introduction

Computer technology entered everyday life approximately in the 18th and 19th century. Daily life styles have complied with this technology and started to evolve. Douglas Engelbart's introduction of the mouse[4] phenomena to the information sector in the 1960s and the widespread use of the personal computer technology accelerated this evolution.

Today the information technology appears in various parts of daily life. From, cell phones to digital photography machines, video cameras to coffee machines, transportation to medical devices, the computer technology takes place in numerous machines. These devices that people interact with in their daily lifes are usually a facility and sometimes a burden we are unable to forsee. Many has experienced a time when they can not put into use a computer based product that they have paid a great deal of money for. The problem here is that we can not figure out how to use the digital tool, but not the product being unable to fulfill what is needed. As *Donal Norman* mentions in his book, "*The Psychopathology of Everyday Things*", it is essential that we become engineers in order to faciliate and speed up the time we spent while using the products we buy (Norman, 2002 p.1). For this reason, the interface is very important in user-computer interactions, because at some point the interface can be seen as the translator that makes the computer language impracticale for the user (Buurman, 2005, p.341). The better the translator is, the better the user understands the language of the computer and interprets his/her needs as the computer will understand. Hence the interaction between the user and the computer will be productive.

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[4] Mouse: Mouse is a computer input device which enables user-computer interaction by pointing

1.2 Technology and Interaction Design

Software based technological devices have led to the need for a new design. In the 1950's and 1960's, the hardware designed by engineers were used by engineers (Preece, et al., 2002 p.7). However, with marketing and the widespread use of computer technology, every individual started to use these hardware. Today, people from every part of the society are already using, demanding for or trying to use technology. That is the point where the interaction designers get involved. *Irene McAra-Mc William*, an academic member of the *Royal College of Art*, defines art as follows;

> "Interactive design is a discipline that 'explores the relationship between people and technology, [occurring] in the space where users and technologies meet, and interaction designers inhabit this space, looking in both directions simultaneously'." (Parker, 2004).

Probably, the most significant difference between Interaction Design and other disciplines is that it studies the interactions between humans and technology. For example; a software engineer's sole interest is to activate the demanded program, for him the utility of the product is not the first concern. For the engineer the behavioral attitude (Cognitive psychology) of the target group that will use the software is not the concern. The engineer's primary goal is to make the program function. However, the interaction designer has to consider interdisciplinary on the relationship that might be established between the user and the output that the computer engineers produce.

The 1970's and 1980's were perhaps the turning point of our lives when the field of informatics is considered. Starting with desktop computers, the adventure of touch-operating interaction came all the way to the cell phones use currently. While the technology has developed, society has started to change parallel to it and this change has led the society to new needs. The user interface came to the fore in the 1970's and 1980's and brought such new needs. The biggest challenge was making the computers usable to non-engineer users. As a result, the software engineers came together with physiologists when developing software since they needed experts on the behaviors and perception of the target group they designed the programs for (Preece, et al., 2002 s.7).

Once the operating systems and GUI[5] concept came forth in order to ease the users interactions with the computers, the designers started to integrate visual items into their designs (Preece, et al., 2002). As a result, the operating systems had been offered as the cyber versions of the physical tables that certain jobs were employed on. The folder icons used and the menus developed in these systems gave the opportunity to the users to carry their physical working tools to their computers. Consequently, the user no longer needed to turn the pages one by one in order to find a specific word in a large document.

In the mid 1980's, the concepts of multimedia[6], voice recognition systems, data visualizations and virtual reality gained attention, and more people started to get involved with technology. Especially with academics leading these subjects and with the development of technology for the education sector, a new period started in the technology-human interactions. The new researches done by academics gave birth to new experience fields and hence became a factor that increased the development process. New professions occurred in the sector such as technologists, developmental psychologists and training experts (Preece, et al., 2002).

With the coming of the 1990's and the 2000's, technology became a very essential part of daily life and started to change the society rapidly. Many more physical environments were converted to the virtual world with the developed technology. The change started as virtual notebooks, tables, graphs, rubbish bins and calculators and continued with grading, report card systems in schools, interactive education CDs[7], hospital and bank records, automatic doors, bus tickets, libraries, vehicles, communication devices, white goods and many more. Many more are being converted to the cyber environment and many physical tools are being eliminated. It is easier and more accessible to preserve, interpret and reach data in the cyber environment and there are many more advantages to list. A very good and basic example is the credit cards where any amount of money can be kept and in case of theft the card can be canceled and the amount can be saved with a single phone call. Nowadays, it is almost impossible for people to live without these computer-based digital devices and tools. Therefore, it is no longer efficient to develop only computer-based interfaces. It is now

[5] GUI – Graphical User Interface: It allows the user to communicate with computer devices. In conventional scope, a GUI consists of windows, icon, menu and pointing (referred to as mouse clicking).

[6] Multimedia is combination of different media forms such as audio, video, text, interactivity and other media possibilities.

[7] CD – Compact Disc

a necessity for the interfaces developed to be usable by non-engineers since technology is a more important part of the community life and there is so much more to take into consideration when making a design.

The new disciplines added with the process of technological development, resulted in the rise of the concept of Interaction Design today. Therefore, whether a device is an efficient platform is more significant than the existence of a 'technological device'. This is the reason why effectiveness is the key factor of Interaction Design. "...it is about developing interactive products that are easy, effective, and enjoyable to use –from the user's perspective." (Preece, et al., 2002 p. 2)

Every technological device is effective to a point but sometimes it is the complexity of the procedure that is the problem. If technology offers a new solution with the "development", the user will naturally expect a development in the social standards the technology operates in. This situation brings a technological paradox with it. At a point Interaction Design is the aim at bringing solutions in order to get ahead of these paradoxes.

1.2.1 Paradoxes and Technology

Every new technological development brings new opportunities. These opportunities sometimes ease our working systems and social lives and at other times are a burden. When a new technological product is in the market, at first it is complex to many customers since it takes time for people to get to using it and because of its differences. After some time as people start to get used to the product, the complexity level decreases, but just as this happens a new product is on its way to the market for the customers' use and the complexity level increases once more with the new products differences. Donald Norman states this situation in his book as follows:

> "The development of a technology tends to follow a U-shaped curve of complexity: starting high; dropping to a low, comfortable level; then climbing again." (Norman, 2002 p. 30)

If technology is seen as the reflection of development then the same situation should apply to the artifact that is introduced with this development. Therefore, the artifact is expected to ease the work done and decrease the work time for the user.

Norman gives an example of the digital watch for this statement and the truth of his 'U complexity' hypothesis can be seen from this example.

Before the emergence of digital watches, we were only informed about the time with the aid of analog watches. A potentiometer was used in order to set the right time. There were no other functions and control mechanisms on the analog watches used. With digital watches, many more new functions were offered the day and month as well as the time and even the different times of other countries and cities. (Figure 1.)

Figure 1. Digital watch[8]

Functions such as an alarm, backlight, chronometer and calculator were added to them. However, most of these functions were not used. Because the technological abilities allowed so many functions in a single device, completely useless functions were put into a device that had a primary function of informing on the time. Only three buttons controlled all of these functions. The user needed to press a combination on these buttons in order to use a certain function, which made the device complex and therefore a bad product design. The product had much better alternatives than the previous versions of analog watches, however fitting so many functions in such a small device brought with it many designing and functionality problems. If digital watches had been efficient products there might not be more people using analog watches instead of digital watches today.

Interaction Design also utilizes from the efficiency or functionality concept. If we elaborate more on the functionality concept we will find many subtitles such as *Effectiveness, Efficiency, Learnability, Memorability.* The design of the multi-functional digital watch does fit some of the concepts while being completely unable to satisfy

[8] http://www.sanaltedarik.com/index.php?act=viewProd&productId=233 (accessed: January 8, 2009)

others (Preece, et al., 2002 p.14), and therefore it is possible to regard it as a useless design.

When we evaluate the digital watch on the concept of *Effectiveness*, it can be seen that some functions of digital watch are useful for the user such as to being able to view the time with the aid of a backlight at night or knowing the week of the day. There are generally no such features for analog watches like backlight or calendar.

When we discuss digital watch according to the *Learnability* concept, digital watches are not so efficient since it is also essential in their production and marketing process to be able to design the right function combination in order for the user to utilize all the functions the digital watch has to offer. This increases the time needed to learn how to use the device and has to do with the *Memorability* concept. Controlling ten parameters with three buttons means a need to memorize a relatively hard combination. Since, all the buttons look alike, at least a change could be made on the buttons with a color or a sign in order to make it easier to remember. However, out of all the versions of these digital watches produced no such solution was brought in any.

Technology expects user to learn a new language for communication with each new interface developed. In a way we are learning or being forced to learn how to communicate again and again every time a new development is made. The situation changes according to the privileges the technology has to offer. For example, in 19th Century communication was established by telegraph. The principle of it was a coding system that produced and stopped the electric signals that were sent according to certain time intervals from which the receiver would decode according to the information it obtained and would convert it into a written material that people could understand. In order to use the telegraph[9] for communication, the coding language had to be known, which was very hard, because, each voice tone that represented a single letter of the alphabet could be heard at certain time intervals. However, in contrast to the digital watch, the telegraph was used for several years for communication purposes, because it offered a system that had no better alternatives (such as being much faster than communication via post when there were large distances) (Bell, et al., 2002). Therefore, no matter how hard it was, people learned the new language the technology needed.

[9] Telegraph is a communications system that transmits and receives signals in accordance with a code of electrical pulses- http://people.unt.edu/joy/school/TheVictorianInternet.pdf (accessed: 08 January 2009) (Standage, 2000).

The digital watch example[10] used by Donald Norman is very useful when discussing Interaction Design. It shows that many functions that are neglected or needless ones that are added make the device inefficient to use. Because of these neglected functions and because the language that was proposed with the digital watch could not be assimilated by the users, nowadays, digital watches are not used considerably and may even be thought of as nostalgic. Since the digital watches[11] that were introduced in 1991 were not the only alternative as a device that had a function of showing the time, the ability to choose made the users tend towards more efficient products.

1.2.2 Society and Technology

"We shape technology, technology shapes us." (Löwgren, et al., 2005).

Since the Industrial Revolution, technology and society have been molding each other. The beginning of the Industrial Revolution[12] in 1770 and the mass production that came with it can be seen as the starting point in the interactions between the society and technology. Since then, the relation between technology and humans has been questioned repeatedly until today and many theories and opinions have been put forward.

These theories and ideas have a significant effect in the formation of computer technologies we interact with today. The most famous of these are Social Determinism and Technical Determinism. Technical determinism claims that development or changes in technology change the manners (behavior), everyday life style and private life of people. Social determinism claims that changes and progress in technology take place by the help of people (Buurman, 2005 p. 27). Since human beings have sometimes tried to keep in pace with the technological reforms while at other times have demanded for better solutions and hence had an effect on the changes made. Reviewing the case of telegraph, it can be seen how we have been shaped by technology. In the 19th century, people had to learn Morse alphabet because there was not a better option of communication, since there was not any other solution to communicate between distant

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[10] (Norman, 2002 s. 31)

[11] Digital watches were introduced in 1991- http://en.wikipedia.org/wiki/Casio_F91W - (accessed: 08 January, 2009).

[12] (Lucie-Smith, 1996)

places. However, today people use telephone and Internet to communicate. Within these interfaces/mediums, people can interact more easily than they could interact with the telegraph. Currently, the only thing we have to learn is how to dial the number of the person that we want to communicate with by pushing the buttons on the phone or to know his electronic mail address. That is to say, technological and social changes do not occur because of any single causality (Löwgren, et al., 2005 p. 142). At certain times, society had to keep with the technology and at other times, technology needs to find ways to change and develop in order to fulfill the demands of society. One of the best examples of this is the development made from telegraph to telephone. Though the telegraph required a complicated language for interaction, it was used for a long time because technology has provided only such means in that era. After years, the same technology made it possible for us to communicate via telephones as a more effective interaction source.

The language we use today is much more basic and understandable then the Morse alphabet used for telegraph. If technology helped us come to this point, then the question arises is what helped the technology to come to such a point. Certainly, human beings developed technology, it is not accurate to link technical changes only to social determinism from here, because the privileges that technology can offer constantly differ with time. Although, scientist are from society they do not act with total correlation with the society they belong to. For this reason, it is not possible to bring the subject down to a single causality. Technology, society and human beings are constantly in interaction. Jonas Löwgren and Erik Stolterman have considered their ideas on the subject with the many different theories and have interpreted it under the title "*We Shape Technology, Technology Shapes Us"* (Löwgren, et al., 2005 p. 142).

> "The people developing technical artifacts are of course members of society, but their work is commonly seen as independent and located outside of the society. Technology development is usually viewed as applied science: Developers apply new scientific findings, which consist of objective and increasingly detailed insights into how nature really works. The technology resulting from this application of scientific findings is then introduced into society and causes certain societal effects, which are unpredictable." (Löwgren, et al., 2005 p. 142).

Both sides have effects on each other. At times, the technological possibilities offered inefficient communication systems people had to accept and apply them if they had no alternatives. At other times, people with options, had refused the solution that technology provided, claiming it to be inconvenient.

Today the development of technology is changed due to certain outside factors. Marketing strategies, advertisements, companies producing technological material and designers have the biggest roles in these developments. Jonas Löwgren and Erik Stolterman state their ideas on this subject as follows:

> "...technology is shaped by societal factors, although both in unilateral or instrumental way. Society is equally shaped by existing technology and technological development. We shape technology, and technology shapes us." (Löwgren, et al., 2005 p. 143).

Therefore the Interaction designer can be identified as a member of the society who takes into consideration the needs and the capacity of the society and designs the technology on behalf of the society. In place of the mouse and keyboard objective interaction methods used since the 1980's, nowadays, multitouch screen interfaces are being developed. The mouse and keyboard have been used for a long duration and during the time span alternative interaction methods have been tried many times.

CHAPTER 2
Technology and Interaction Paradigms

2.1 From ‘Memex’ to ‘Mouse’

Memex is an information storage interface proposed by Vannevar Bush in his article *As We May Think* in 1939 (Figure 2). The article is an important progress in the development of personal computer and GUI concepts since it allows for the user to store and access the information he uses in a research.

By presenting *Memex*, Bush aims to control the huge amount of information increasing day by day. Since the amount of information increases, it becomes harder to assess performed studies for those who want to do new researches. For instance, it may take years to make a literature search for a researcher without using any computer or Internet technology. Bush suggests *Memex* in order to prevent such serious time losses. He describes it as;

> “a device in which an individual stores all his books, records and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory.” (Buurman, 2005 p. 29)

With this prototype, Bush aims the user to keep his/her written documents and to reach the document with relevant subject quickly when required. *Memex* is a prototype theoretically offered in the article. In fact, it is an interface, which has never been actualized but has inspired many scientists and designers. Today, many specialists and information scientists give references to *Memex* of Bush (Buurman, 2005).

One of the researchers who were influenced by Bush’s article is Douglas Engelbart. If Bush is the father of today’s computer technology, then Engelbart can be regarded as the man who put this idea into practice (Buurman, 2005).

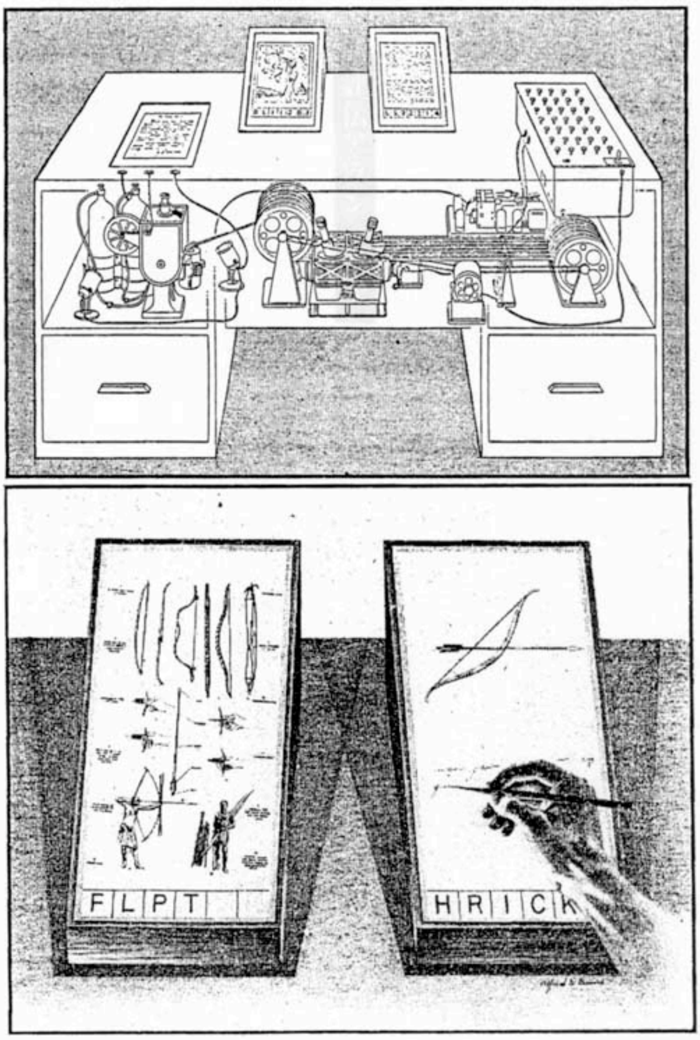

Figure 2. Sketches of Memex- www.multimedialab.be (accessed: 09 January, 2009)

Engelbart formed a research group in Stanford Research Institute between 1957 and 1977. With this group, he performed many studies in order to develop human-computer interactions. There are many innovative instruments among the studies of this group that provides human-computer interaction. However, the most important of them is the first version of ‘mouse’ we use today (Figure 3). *oN-Line System (NLS) is* the software Engelbart and his colleagues developed in order for the user to be able to interact with the computer via ‘mouse’ and the keyboard. *NLS* included a word processing system with segmentation tools, a documentation administration system, a teleconferencing system, a hypertext[13] and interfaces enabling simple graphical processes (2005, p. 33).

Figure 3. Douglas Engelbart's 'mouse' - http://en.wikipedia.org/wiki/File:Firstmouseunderside.jpg (accessed: 09 January, 2009)

This interface developed by Engelbart and others was introduced publicly for the first time in a conference[14] held in San Francisco in 1968. In the conference, Douglas Engelbart presented the interaction methods between computer and the user by demonstrating the use of 'mouse' and the keyboard personally.

It is obvious that *Memex* is the source of inspiration for Engelbart since his mouse-based system is a similar technology that simplifies the interaction language by taking the society into consideration just like *Memex*. According to Engelbart, interaction between computer and human is a very complex and mechanical process. Due to the hardness of the interaction, non-experts have difficulty to use computers. One of the major purposes of Engelbart for developing 'mouse' was to enable the user to interact with the computer without the requirement of any computer language skills. Thus, the 'mouse' shortly became one of the main digital tools that translate complex computer language to the non-expert user.

[13] Hypertext is text, displayed on a computer, with references (hyperlinks) to other text that the reader can immediately follow, usually by a mouse click or key press sequence - http://en.wikipedia.org/wiki/Hypertext (accessed: 09 January, 2009).

[14] The American Federation of Information Processing Societies (AIFPS) in San Francisco. The video of Douglas Engelbart's presentation can be watched from Stanford University's server - http://sloan.stanford.edu/mousesite/1968Demo.html (accessed: 09 January, 2009).

With a social determinist approach, it can be argued that Engelbart manipulates technology in the name of society. However, according to Engelbart, changes arising on technology and society never depend on a unilateral causality. In other words, neither just society affects technology nor vice versa. Technology and society affects each other mutually (Buurman, 2005).

2.2 Father of WIMP Paradigm

"...computer as a medium rather than a tool." (2005, p. 34)

'Mouse' phenomenon, which was brought to the information world by Douglas Engelbart in 1968, widened the horizons of many researchers and companies. Alan Kay is one of these researchers who developed *Dynabook* (Figure 4), which is a portable interface in which the user may store written, audible and visual files (Buurman, 2005). *Dynabook* is a prototype just like *Memex* of Bush and one of the first sparks that created whole PC and GUI concepts. As Kay planned *Dynabook* to be totally a dynamic computer interface for the user, it is one of the earliest ideas developed for today's laptops as well.

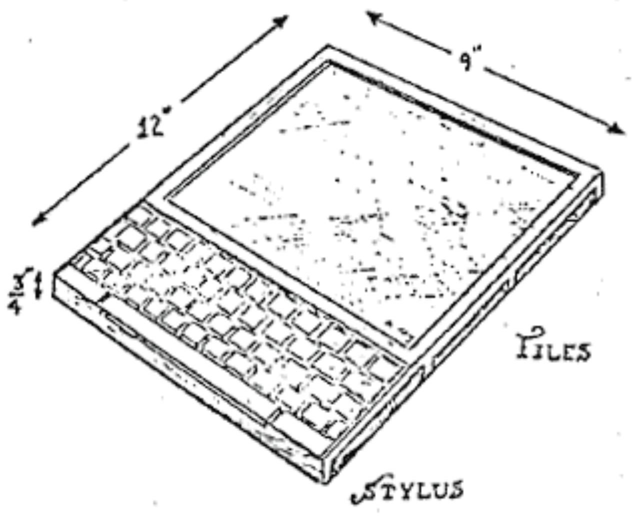

Figure 4. The Dynabook's original illustration in Alan C. Kay's 1972 paper - http://en.wikipedia.org/wiki/Dynabook (accessed: January 10, 2009)

In 1971, Kay went to the Xerox PARC[15] with his *Dynabook* idea where *Dynabook* prototype could not put into practice due to technological deficiency of the time. Thereupon, between 1972 and 1975 Kay developed *Xerox Alto* (Figure 5), which is one of the first personal workstations (Personal Computer) in the history, based on the interface of *Dynabook*. Since Kay designed it as an interface to be used by office personnel, Xerox Alto had a graphical interface designed as a virtual model of a real work office (Manovich, 2001). Thus, representing the functions of a real work office, there were many available applications in *Xerox Alto*.

Figure 5. Xerox Alto PC and the first laser printer- http://ed-thelen.org/comp-hist/Shustek/ShustekTour-05.html (accessed: 10 January, 2009).

These applications were like virtual copies of tools that could be on an office desk. Screenshots of these tools were small icons. For instance, when a user wanted to use calculator, he/she could launch it by clicking on an icon labeled as 'calculator'. After clicking it, a visual window was opened and user could see a visual model of a calculator used in the real world. In order to interact with this visual calculator, user needed to use mouse and keyboard. In this context, with all the practicalities he introduced in human-computer interaction in 1970's, Kay could be considered as one of the forerunners who developed the interaction language that a computer user may need

15 Xerox PARC: Xerox Palo Alto Research Center.

to learn. Thanks to him, today almost all computer users are familiar with the concepts such as Windows, icon, menu, pointing and Graphical User Interface.

Interestingly, Xerox Alto has never been offered for sale as a commercial product. Xerox Corporation just used this product for advertisements. Instead, they put it on the market with the name of Xerox Star in 1981. However, since it could not reach expected commercial success, Xerox Corporation preferred to produce only the printer[16] instead of the personal computer. Being unable to reach this commercial success is really an interesting case. Because, 'mouse' focused user interfaces of Macintosh[17] and Microsoft[18] today are based on a model projected by Kay.

The position of Kay within today's information world is an indisputable truth. Computer programs having WIMP[19] based GUI[20], which became traditional today have come into our lives by means of Alan Kay.

If we accept that first personal computers were put on the market in 1980,s, we can say that computer-user interaction method have stayed unchanged for a quarter of a century. WIMP focused user interfaces have accomplished their functions since 1980,s. However, new methods are researched by the influence of the latest computer technology developments. Because computers now can execute instruction per seconds faster than the past. And this situation can offer more opportunities for the user. PCs produced by Xerox and Macintosh in 1980's could launch only one program. Thus, WIMP method was not a problem for the user. However, increasing program amount and computer technology spread all around our lives today makes WIMP method inadequate. Therefore, new methods are sought for interacting with computer.

2.3 Post GUI and Multitouch Screens

"The real-time screen became interactive." (Manovich, 2001 p. 102)

Multi-touch Screen is a technology which allows more than one user to interact directly with computer by using more than one simultaneous finger (Figure 6). NUI Group[21] defines multi-touch interfaces on the electronic book they published as;

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16 Xerox Corporation developed the first laser printers.
17 Macintosh is another precursor of PC, GUI and Operating System.
18 Microsoft Corporation is software and operating systems manufacturer.
19 General terminology of Windows, icon, menu, pointing.
20 General terminology of Graphical User Interface.

> “a set of interaction techniques that allow computer users to control graphical applications with several fingers. Multi-touch devices consist of a touch screen (e.g., computer display, table, wall) or touchpad, as well as software that recognizes multiple simultaneous touch points, as opposed to the standard touch-screen (e.g. computer touchpad, ATM), which recognizes only one touch point.” (Çetin, et al., 2009)

Figure 6. A Multitouch Screen Interface - http://www.flickr.com/photos/ideum/3250777987/in/photostream/ (accessed: January 11, 2009)

Engelbart developed many methods and tools for interacting with computer after the introduction of the ‘mouse’ in 1968. However, many of these studies are based on communicating with again a physical object. Multitouch technology provides an interaction opportunity to the user by a direct touch. Traditional human-computer interaction is based completely on physical objects. User supplies interaction with computer by these digital artifacts. By multi-touch technology, the user can directly interact by touching the visual icons that he/she sees. In other words, interaction with computers is provided by direct physical technique. There is no need for an extra gear

[21] “NUI Group founded in 2006, Natural User Interface Group (~ NUI Group) is an interactive media community researching and creating open source machine sensing techniques to benefit artistic, commercial and educational applications. It’s the largest online (~5000+) open source community related to the open study of Natural User Interfaces. (Çetin, et al., 2009 p. ii)”

tool such as mouse or keyboard to do that. This provides speed and ease to use in many aspects. The most important is that WIMP concept gets a new dimension.

Traditional interaction paradigms allow user to control his/her interaction with computer over a single point. As the user chooses the program to launch, program window is opened and the user runs program functions by mouse. However, the user cannot run more than one function at a time because cursor is a single point. Thus, the user cannot work with more than one program. On the other hand, each finger of the user works as a separate mouse on multi-touch technology. Working on a single multi-touch screen interface by more than one user at a time increases this control number. Thus, user(s) may have opportunity to do more than one process at a time.

Interaction interfaces designed for multitouch are called Tangible User Interface (TUI) or Post GUI in the literature. The source of this technology, which has become prevalent during last five years, dates back to 1960's. In fact, Ivan Sutherland is one of those who made first study on this issue. *Sketchpad* (Figure 7) introduced by Sutherland in 1963 enables user to interact directly with computer by means of a *light pen*[22] (Sherman, et al., 2003). Sutherland defines *Sketchpad* in his thesis as follows;

> "The Sketchpad system uses drawing as a novel communication medium for a computer. The system contains input, output, and computation programs, which enable it to interpret information drawn directly on a computer display. It has been used to draw electrical, mechanical, scientific, mathematical, and animated drawings; it is a general purpose system." (Sutherland, 1963 p. 9)

We can say that the interface introduced by Sutherland in 1963, established the idea of multi-touch screen interface. Because, multitouch interfaces like *Sketchpad* do not use computer screen only as a tool displaying virtual reality but also for direct interaction purpose (Manovich, 2001).

Even though studies on interaction by touching have a long past, this technology has being used by the society only for a few years. Invention of *lightpen* used by Sutherland for interacting with *Sketchpad* is earlier than the invention of the mouse. As mentioned in the website of Bill Buxton[23], multi-touch technology has widely developed itself in

[22] Light pen is a tool to set pointer's x and y position on the computer screen.
[23] Bill Buxton is researcher at Microsoft Research Department http://www.billbuxton.com/multitouchOverview.html (accessed: January 11, 2009).

the last five years. It has a past for only 4-5 years[24] as a commercial product. Studies being performed beginning from 1960's are the development phase passed for being able to use multi-touch technology functionally.

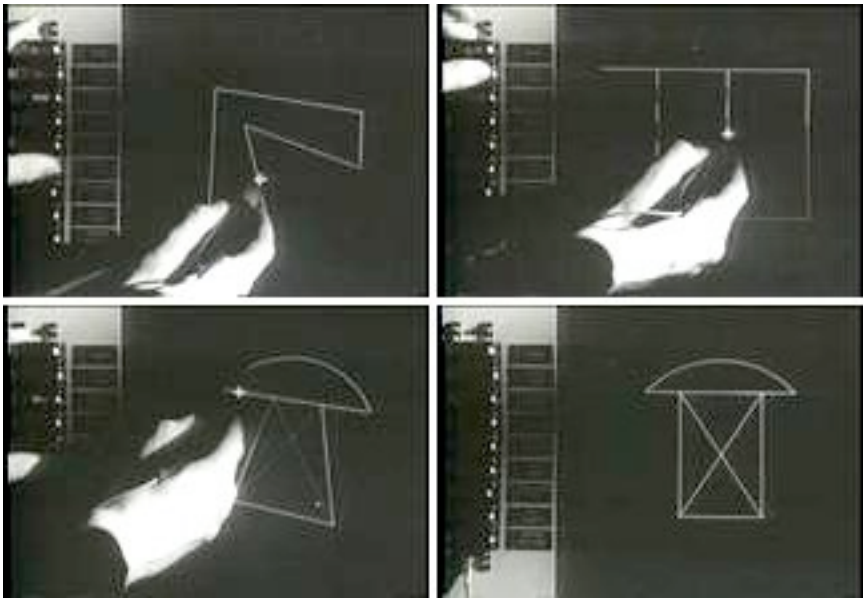

Figure 7. Ivan Sutherland's Sketchpad in use
http://en.wikipedia.org/wiki/Sketchpad(accessed: January 11, 2009)

Mouse is the most consistent translator offered by technology to the computer users for understanding the complex computer language in 1970s. It is yet the most dominant interaction device being used today.

Then if studies began on touch style interaction in 1960s, why did not this method be concentrated on? It can be thought here again that technology directs societies. However, there are other very important factors here, which are producers of information world. Domination of Macintosh and Microsoft is an indisputable truth on that issue. Macintosh has been providing its own operating systems together with the purchase of their computers for years. If a user wants to use Macintosh, he/she cannot use another operating system efficiently with it. Therefore, the situation limits the user in terms of computer technology. It is the same for Microsoft as well. If Microsoft did not put its first commercial multi-touch screen[25] on the market in 2007, multi-touch style interaction would not have become so popular for the last two years.

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[24] According to Bill Buxton the first commercial product, which is using multi-touch technology http://www.billbuxton.com/multitouchOverview.html (accessed: January 11, 2009).

[25] Microsoft Surface is a multi-touch screen interface.

Nowadays, it is obvious that relation between technology and society is mutual. However, as it is mentioned in the previous section, there are many factors affecting this relation. Another factor is the information market. Major companies, which keep the leading position in the market generally, decide when to introduce a technology. It is inevitable to continue with solutions offered by them unless they offer new products to the consumer.

CHAPTER 3
Music and New Audio Culture

3.1 Music to Sound

"I dream of instruments obedient to my thought and which with their contribution of a whole new world of unsuspected sounds, will lend themselves to the exigencies of my inner rhythm." -Edgard Varese[26]

Technological improvements in the 20th century has given new meanings to concept of sound and offered different implications for the sonic arts. The interaction language previously mentioned, is a valid communication style for sonic arts as well. Various computer based sound interfaces enabled mankind to produce new forms of music. The most important factors that helped the formation of the new interaction languages are the researches made on sound in the 1950's. Starting with the production of sound with the newly available digital technology, the ground rules for making music became subject to a breakthrough and the creation of music slowly evolved into new directions. One of the most important names that influenced this breakthrough is Luigi Russolo (b. 1900). The alternative forms for making musing he suggested in his manifest *The Art of Noises,* written in 1913, have opened new grounds for traditional music production. In his manifest, Luigi Russolo states that traditional orchestral instruments are incapable of reflecting the soul, energy and the noise of modern life (Cox, et al., 2004). Known as a futurist artist, originally a painter, Russolo invented *noise instruments*[27] (Figure 8) and showed that music can be composed not only with sounds that are in harmony but also with sounds defined as 'noise'. With the mechanical devices he invented, he was able to imitate a whole range of sounds such as explosion sounds, vehicle sounds and the sounds of nature and gave many concerts with an orchestra of these devices. As one can

[26] Quated from (Holmes, 2008 p. 3)
[27] In some sources, it writes 'Intonarumori' as 'Noise instruments'

imagine, the devices he presents in the orchestra are very different form the traditional musical instruments. They are neither wind instruments nor percussions, instead they look like boxes of different sizes with mechanical arms and one can interact with the devices to make sounds by spinning those arms.

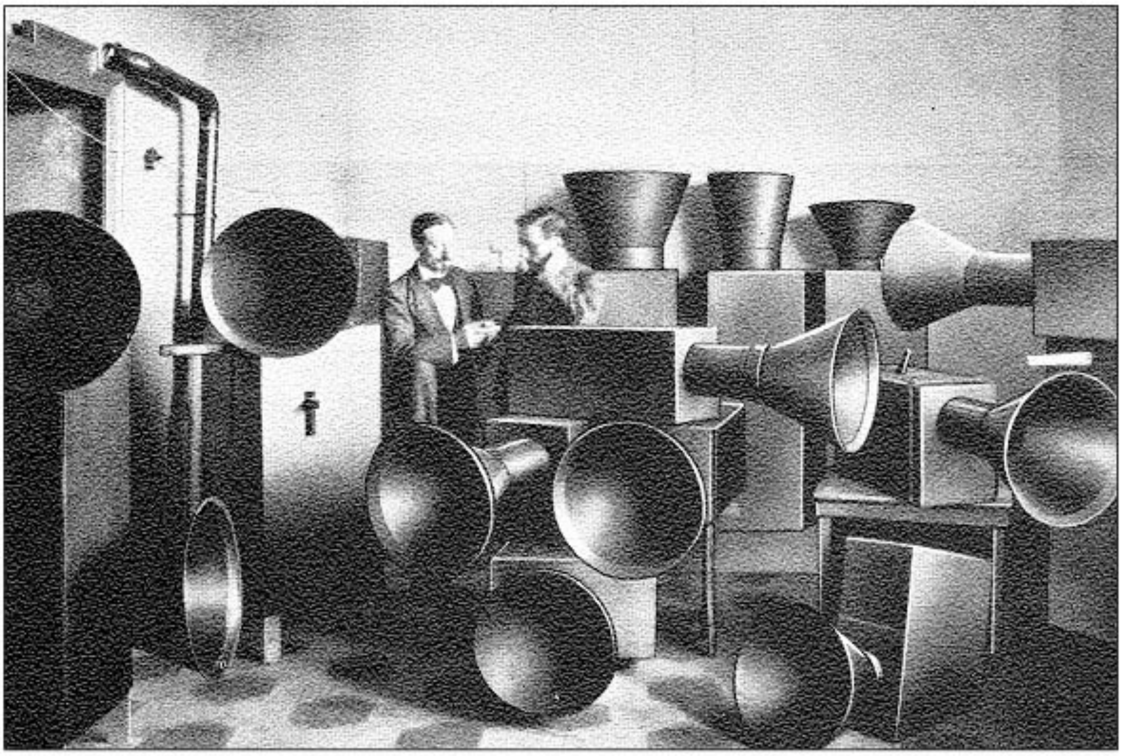

Figure 8. Luigi Russolo in 1913 with his mechanical orchestra (Russolo, 1967).

Russolo mechanically invented the first prototype of the digital synthesisers[28] that are being used today. Moreover, he is among the first names to realize that 'sound' has gained a new meaning after the Industrial Revolution. Additionally, the devices he presents are important in the interaction of mankind with technology. Russolo's invention of these devices has influenced many artists after him (Cox, et al., 2004). John Cage, Pierre Schaeffer, Edgard Varese, Iannis Xenakis, Karlheinz Stockhausen are among those who were influenced by Russlo’s works and contributed widely in the process that led to the stages of music production today.

[28] Synthesiser is an electronic instrument that is capable of producing a variety of sounds by generating and combining signals of different frequencies. http://en.wikipedia.org/wiki/Synthesiser (accessed: January 13, 2009)

The common ground that all these artists meet is the 'sound'. Sound existed throughout the history of the world and it will exist as long as life on earth lasts. John Cage's anechoic chamber experience is the best example for the existence of sound. He states his vision on sound after this experience as follows;

> “There is no such thing as an empty space or an empty time. There is always something to see, something to hear. In fact, try as we may to make a silence, we cannot. For certain engineering purposes, it is desirable to have as silent a situation as possible. Such a room is called an anechoic chamber [...] a room without echoes. I entered one at Harvard University several years ago and hear two sounds, one high and one low. When I described them to the engineer in charge, he informed me that the high one was my nervous system in operation, the low one my blood in circulation. Until I die there will be sounds. And they will continue following my death.” (Cox, et al., 2004 p. 4)

As Cage states, sound will always exist. Traditional musical instruments are just limitations of sound according to some spesific rules and forms. Nevertheless, there exists an infinite alternatives of sound in the universe. In that respect, it would be unfair to sound, trying to make music with the limited offerings of traditional musical instruments. The biggest contribution of the 20th century composers in the audio culture is their efforts in liberating music and making all the existing sounds audible. Technology offers new possibilities to produce sound just as it was benefited in the formation of telegraph and digital watches. As it is explained in chapter 2, these possibilities have brought along the necessity for us to form a new communication language.

3.2 Sounds and Technology

One of the major reasons behind the intensive work done on sound studies is the invention of phonograph[29]. Thanks to phonograph, sound became recordable and experimented. Being able to record sound was beneficial for many researchers and composers in order them to develop new perspectives on sound (Wishart, 1996). In 1920, researcher Leon Theremin invented one of the first electronic instruments in the history of sound which was named after its inventor as *Theremin*. The working principle

[29] Thomas Alva Edison invented the first phonograph on November 21, 1877 (Norman, 2004).

of *Theremin* is as such; the electrical signals are processed and converted to analogous signals via various circuits. The invention of *Theremin* was revolutionary in many respects for the time it was invented. The control interface it operates on is highly differentiated. There are two antennas placed on top of the device and *Theremin* contains a few knobs to set the characteristics of the signals to be produced, which is unlike any musical instruments of its time. In that respect, the interface that Leon Theremin presents to musicians completely requires a new communication language. While one of the antennas on top of *Theremin* sets the volume level, the other one controls the pitch of the sound. The user, by moving his/her hands in air on the antennas, tries to manipulate the sound (Figure 9).

Figure 9. Leon Theremin is performing with his *Theremin* instrument - http://media.photobucket.com/image/theremin/trickmirror0/theremin.jpg (accessed: January 13, 2009)

Theremin is a highly innovative musical instrument in terms of its usage and interface. It can produce semi tones which can not be produced by keyboards or some stringed instruments, and that provides the user with many opportunities while in composing. The improvements in technology has a great effect on the invention of *Theremin*. Electronical engineer and cello player Leon Theremin was able to use and shape technology in line of his needs and wishes, and the resulting product, as mentioned earlier, suggests a new communication language.

Within the audio culture, technology is not only influenced by needs of the society but also the improvements that the audio culture witnesses itself. For instance, Edison's aim at inventing the phonograph was completely different than the capabilities of the final output; “he sought to develop a device that could take the phonautographic signatures of vocal sounds and automatically transcribe them into the appropriate letter.” (Kahn, 1999 p. 91) However, later on, he discovered that the device he made could record sound and play it back. In that respect, it can be said that Edison created one of the first sound recording devices of the history and that example shows how technology shapes itself. What Jonas Löwgren ve Erik Stolterman state on the issue is as follows;

> “...technology itself shapes new technology. The main part of all technological development does in fact consist of modifications and additions to existing technological artifacts. Many important inventions were demonstrably inspired by technology, perhaps merely transferred to a new domain of application. There, of course, more factors influencing the shaping of technology than just technology itself, however.” (Löwgren, et al., 2005 p. 143)

It is clear that while Edison was willing to develop a spesific device by using technology, what he was working on was transformed into a completely different area. As seen in the case of phonograph, even though technology shapes itself, if it were not for the idea that Edison came up with, there would not be any phonograph.

3.3 Computers and Music

Starting from the 1960's, computers have made their ways into daily life on an accelerating pace and designers kept developing various programs for computers. Since the number of computer users increased, demands for new software programs also increased. The demand is even higher among the people who work with sound and computer technologies have a lot to offer.

The relation between sound and computer technologies were formed back in early 1950's (Holmes, 2008), thanks to the researches that many contemporary musicians carried on in the field of sound. In that respect, Iannis Xenakis is one of important names that helped to build computer-sound relation. In 1956, he used computer for his work *Stockhastic Music*[30], not in order to produce sound but to calculate the probabilities in his compositions.

In the 1980's, after the market met personal computers, computer programs on sound were introduced and developed constantly. Such as the office desktop concept, the programs concerning music were designed in a similar manner. For instance; synthesizer models which generate electronic sound in a computer environment were designed. Moreover, the software synthesizers' GUIs designed today are almost the same as their originals (Figure 10). The only difference is that a mouse is needed to interact with the synthesizer in the computer.

(a) (b)

Figure 10. (a) Look of Software Synthesizer (b) Look of Hardware Synthesizer http://namm.harmony-central.com (accessed: accessed January 14, 2009).

As one can image looking at the figures above, it is not an easy task to interact with a software synthesiser only by using a mouse. It is not possible to control the keyboard just using one pointer. Both interfaces in the figures above generate sound digitally.

30 A term coined by Iannis Xenakis to describe his use of models from probability theory in the composition of musical works (Cox, et al., 2004 p. 416).

However, computers offer much more in that respect. Generating sound with a hardware interface is only limited to the circuits and microcontrollers it has, whereas the situation is slightly different with the software synthesiser. Software synthesisers have many advantages such as the very short time up to only few seconds that is spent to reassemble the preset that was just dispatched after using so many knobs and cables to connect on the interface. Software synthesisers are convenient for the users to save their presets to the computer with a name they prefer. This is not possible with the hardware synthesiser. Additionally, it is possible to add new sounds to the software synthesiser and synthesise them, which is also not possible with the hardware synthesizers. Possibly the best advantage of the software synthesisers is their sizes. They can be easily transported on a portable computer, and the user is able to make music wherever he/she pleases. However, the difficulty of intracting with a software synthesiser is that the user has to use computer mouse and keyboard in order to compose a piece. In other words, what technology has to ask for what it offers is the creation of a communication language. Yet, that process is not convenient and efficient when completed with only a mouse. That is why the control interfaces that can communicate with the computer via MIDI are developed. MIDI controllers have various types and they differ according to software chosen as well. For example, MIDI keyboards are used for synthesisers like the one in Figure 9. The interfaces of those keyboards are exactly the same as the traditional pianos. This way, the user is able to use a GUI developed with a synthesiser concept that is the same as a hardware synthesiser usage. However, there is still a mouse required for the interaction to take place. In fact, these interfaces make the interaction method harder instead of making it easier, because, this time, the user has to both operate the MIDI keyboard and the mouse to interact with the computer. Although the MIDI keyboards provide the user with more than one interaction point, it is not easier to use them compared to the hardware synthesiser.

It has been only five decades since the computer technology emerged and it has been improving very rapidly. While the first personal computers of the 1980's needed so much time to run a single program, today it is possible to run several programs at once efficiently. Yet, as in the case of sound interfaces, interaction methods fail to be sufficient. No matter how easy the interaction language designers developed might get, softwares cannot be operated without a mouse or keyboard interfaces. That is why designers and musicians seek new interaction methods. In that respect, multi-touch screens satisfy an enormous need but the need for a communication language still remains.

3.3.1 Multitouch Screens as New Musical Interface

As mentioned in the previous section, multi-touch screens provide the user more than one control points at the same time so that the user can interact with the computer on more than one point at the same time. In that respect, music making, and sound processing and live performing with multitouch screens become highly advantageous. Moreover, the possibility of having multi-users increases the variety of the possible output.

Reactable (Figure 11), developed in 2003 by the Universitat Pompeu Fabra students, is one of the first electronic music instruments that use a multi-touch screen interface. It is a new interface developed on the basis of the operational methods of the hardware synthesizers mentioned above. The user may interact with *Reactable* directly by using his/her hands, or he/she might prefer to use the objects seen in Figure 10 to interact with.

Figure 11. Reactable is collaborative electronic music instrument with a tabletop tangible multi-touch interface. http://mtg.upf.edu (accessed: January 14, 2009)

These objects can be grouped into four considering their functions; producing sound, adding effects to the produced sound, filtering the sound, and finally the controllers. In that respect, *Reactable* requires its users to learn a completely new communication language. The sound takes shape depending on the distance, angles, and the relations of the objects. For example, when the user wants to generate sound, he/she puts the object on the table. This is the same process as touching a key on the keyboard when synthesizers are used. The keys on the keyboard tell the user which notes he/she plays. Thereby, the user can decide what he/she is going to play in the performance according to other performers. This is not possible with the *Reactable*. After the user starts to produce sound, he/she cannot get any feedbacks even on the frequency of the sound. This situation might force users to trust their senses and ears without knowing how they generate the sound. This uncertainty is also noted when applying effects on the sound. The shapes on the objects enabling the interaction give information to the user about the category of the object to be selected. But the user cannot predict what kind of a reaction will take place on the side of the object and that makes *Reactable* more of a musical interface, rather than a musical instrument. The most important part missing in *Reactable* is that; it is not able to give any theoretical feedbacks on the objects. Even though the graphical interface displays the visual form of the sound wave, predicting the tune of the sound just by looking at the graphics still remains as a problem.

Reactable is still popular although it is missing some crucial points because it removes the mouse and the keyboard and enables interaction only by touching. However, acting in harmony with the other performers is highly difficult with *Reactable*. Furthermore, even a small deviation of the places of the objects might result in an unexpected reaction. Thus, users may not perform their performance or generate the same sound again because an interface to save the user's presets is not readily designed. The only possible solution to this problem is to record the performance with a video camera, but still, it will not be the most efficient solution.

Reactable as mentioned above has a completely new and innovative interface but it also lacks so many crucial points. As the designers of Reactable note; "The way the Reactable works is deeply inspired by modular analogue synthesizers such as those developed by Bob Moog in the early 60s." (Jordà, et al., 2009). The most crucial deficiency of the *Reactable* is that it focuses only on the ways of sound processing. The user can interact with *Reactable* more easily and effectively than the traditional methods, but the feedback which he/she recieves after the performance is not adequate. This deficiency might trouble the user during the performance.

Technology provides unquestionable advantages with the introduction of the multi-touch screens, and the designer plays a very important role in deciding on the interaction language that the user will require to communicate with that technology. *Reactable* exists to be a good example on the issue. In many respects, *Reactable* is a wonder of design, but it is not satisfactory in providing the user the necessary feedbacks on sound which is the most important thing for a musician. This is a defect that might make *Reactable* become useless in some certain situations. Additionaly, the amount of the objects that are used for interaction is considerably a lot. It takes a very long time to learn all the objects that add up almost to fourty. *Reactable* removed the keyboard and mouse from the workspace, but using fourty different objects requires a much more complicated communication language no matter how easy to use the interaction method.

CHAPTER 4
Squatouch: Tangible Musical Interface

4.1 Project Description

Sound editing and synthesis softwares offer several opportunities to the users. However, interaction between user and computer becomes more difficult due to WIMP paradigm. Designers have developed MIDI controllers to eliminate this problem. However, even if MIDI controllers provide easier interaction practices with computers, users still have to use 'mouse' and 'keyboard' in order to use these sound softwares. Therefore, many of the sound softwares cannot be used effectively even though these softwares have more capabilities than analog instruments. In this respect, *Squatouch: Object Oriented Sounds/Tangible Musical Interface* proposes a new interaction technique and communication language to the computer users. This new interaction technique allows computer users to control graphical applications with several fingers.

4.2 Process

Process for the project involves four major parts. At the first phase, a widespread research was made on multi-touch screens nearly for five months. At the end of this research, Jef Han's FTIR[31] method was chosen to develop multi-touch screen because of its consistency. At the second phase, technical design of *Squatouch* was made.

[31] Frustrated Total Internal Reflection: frustrated total internal reflection (FTIR), a technique familiar to the biometrics community where it is used for fingerprint image acquisition. It acquires true touch information at high spatial and temporal resolutions, and is scalable to very large installations. http://cs.nyu.edu/~jhan/ftirsense/index.html (accessed: January 20, 2009)

Besides that, various materials were tested to decrease the costs and increase the usability at technical design process. At the third phase, sound synthesis and editing applications were analyzed and musical interface was designed with 'Max5' visual programming environment. Lastly, graphic design of *Squatouch* interface was made.

4.2.1 Multitouch Screens

Natural User Interface Group describes multitouch screen as;

> "a set of interaction techniques that allow computer users to control graphical applications with several fingers. Multi-touch devices consist of a touch screen (e.g., computer display, table, wall) or touchpad, as well as software that recognizes multiple simultaneous touch points, as opposed to the standard touch-screen (e.g. computer touchpad, ATM), which recognizes only one touch point." (Çetin, et al., 2009).

Multi-touch screens generally consist of five sections. These are; a light source, an interaction surface, a camera, software and a display unit (projector), which allows users to get visual feedback. In general, the configuration of a multi-touch screen is the interaction surface coated with light beam. When user contacts with the surface, the distribution of light rays is altered. This contact point is detected by the camera and is sent to computer to be processed. Then, the projector unit displays visual feedback onto the interaction surface. Thereby, user can interact with interface directly by touching. As mentioned in the previous sections, a 'keyboard' or a 'mouse' is not needed along with multi-touch screen interface, for the end user to interact with computer.

Today, there is no single method to build a multitouch screen. Academics, researchers and designers develop many multi-touch screen techniques.

4.2.1.1 Frustrated Total Internal Reflection (FTIR)

FTIR is a name used by the multi-touch community to describe an optical multi-touch methodology developed by Jef Han (Çetin, et al., 2009). This method is based on Total Internal Reflection. Natural User Group describes FTIR as;

> "Light within a transparent channel of low refractive index will reflect internally until an object with a higher refractive index, such as a finger frustrates the surface thus lighting up the frustrated area"

Han proposes FTIR technique at his web page[32] with the schematic shown at Figure 12. Here, IR LEDs are placed on the side surfaces of acrylic in order to spread IR light inside the interaction surface as seen at Figure 12. So, IR light that is applied from the side surfaces is reflected onto the acrylic. When the user touches to acrylic surface, the IR light rays are frustrated at this touch point and this frustrated IR light is scattered downwards to the camera. When the user stops touching onto acrylic, the reflection of the light beam turns back to its default settings.

The reason why IR light is used as the light source is that, the frequency of the IR light is lower than the visible light. This has many advantages. First of all, human eye cannot sense IR light, but IR cameras can. On the other hand, surface calibration becomes easier, because light sources (visible light range) other than IR light are sensed much less by IR camera.

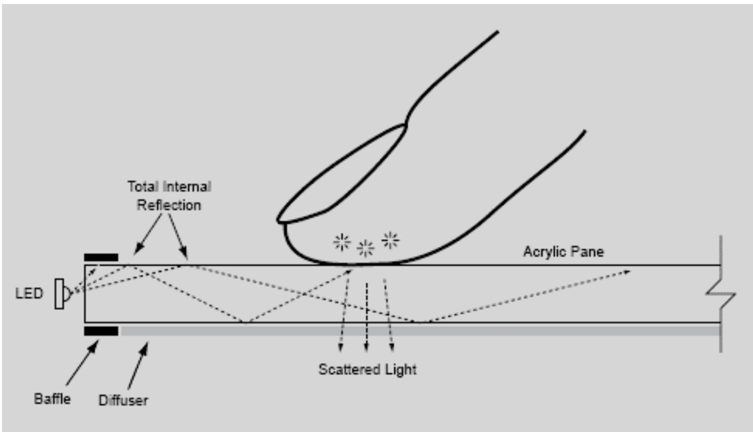

Figure 12. Jef Han's schematic for FTIR method

In many respects, FTIR technique gives more reliable results in comparison to the DI technique. However, it is one of the hardest techniques to build a multi-touch screen with. In this technique, designer should have technical and practical knowledge to setup a FTIR based multi-touch screen. For instance, IR light sources (infrared illuminators) that are required in DI technique can be found readily at any electronics shop. However,

[32] http://cs.nyu.edu/~jhan/ftirsense/ (accessed: 25 July, 2009)

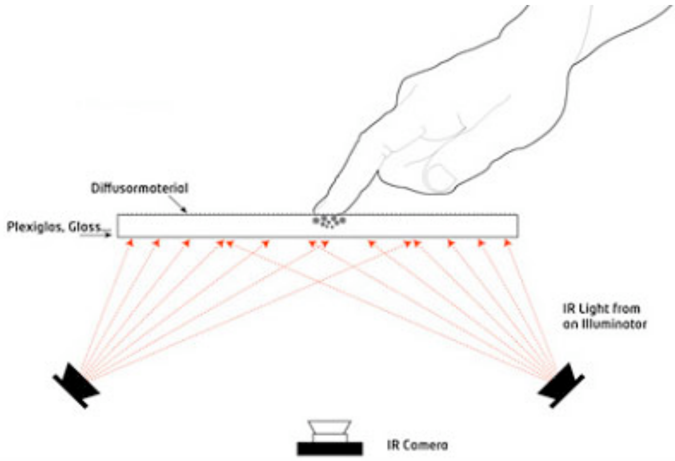

Figure 13. Rear Diffuse Illumination Schematics (Çetin, et al., 2009).

there are not ready-assembled IR LED frames at the shops for FTIR setup purposes. Therefore, designer has to solder LEDs one by one and make technical calculations to construct a FTIR style multi-touch screen. All of these technical calculations, electrical wirings and power managements should be done accurately. Otherwise, interaction surface will be less sensitive to user touches. Preparing Compliant Surface for multi-touch screen is another challenging part of FTIR setup. A compliant surface is a silicon based overlay placed above the interaction surface (acrylic, plexiglass). The compliant surface enhances the touch points and gives user more robust blobs, particularly when dragging, as his/her finger will have less adhesion to the surface (Çetin, et al., 2009). Another advantage of compliant surface is that it transforms touch surface pressure to more sensitive. It is impossible to make touch surface pressure sensitive without a compliant surface.

There are various techniques to construct stable multi-touch hardware systems today. Many of these techniques have advantages and disadvantages comparatively.

4.3 Technical Design

Technical design of the project consists of two main sections. While the first section is about gathering and assembling the hardware, second section consists of information about the developed multi-touch application for the established hardware. The reason behind the preparation of this part is to include technical information about the background of the multi-touch screen interface that has been prepared by Jefferson

Han's[33] FTIR technique. The reason why Jefferson Han's theoretical model is followed [34] is financial and the results it provides are almost the same with the market precedents. For example, the standard sale price of *Microsoft Surface* developed by Microsoft Cooperation is about 20.000 $, whereas *Squatouch* physical interface costs about 1000 $.

In this regard, another reason for the preparation of this part is to prepare the multi-touch screen and provide a resource for the designers that are willing to develop application for the system. Many Internet based sources and documents on building a multi-touch screen, however, most of them are insufficient and lack clear and adequate explanation. These documents may not only cause serious time loss but also financial loss. To avoid this kind of situations, in this project, all the equipments and the usage of the equipments are photographed and described in detail.

4.3.1 The Hardware

The hardware section contains the equipment list used for the project. The information on preparation of the materials and other alternative materials are also provided as follows:

- 40x50x0.8 cm Plexiglass (Advised; thicknesses are between 0,8-1,2 cm)
- 940 nm IR[35] LEDs x 6 (Advised; 850 nm - 940 nm IR LED of any manufacturer)
- 27 ohm Resistors x 10 and 56 ohm Resistor x 1
- 12 Volt and 1600 mA DC power supply
- Logitech Webcam with removed IR blocking filter (Advised; a cam that can provide 30 fps and at least a resolution of 640x480 pixels)
- IR Filter (can be removed from any IR TV Remote Control device) to block visible light and enable IR light to pass (Advised; The limits of the preferred Low Pass Filter should not be lower than the wavelength of the IR LED. For example; the allowed limits of the LPF[36] filter is between 800nm-900nm. If anyone use an IR LED with a

[33] Jefferson Han is a research scientist from New York University. For more information visit http://en.wikipedia.org/wiki/Jeff_Han (accessed: January 6, 2009)

[34] More information about Jefferson Han's multitouch screen model can be gathered from http://cs.nyu.edu/~jhan/ftirsense/index.html (accessed: January 11, 2009)

[35] IR: Infrared radiation is electromagnetic radiation whose wavelength is longer than that of visible light (400-700 nm) – http://en.wikipedia.org/wiki/Infrared (accessed: January 6, 2009)

[36] LPF: Low Pass Filter

wavelength of 940 nm with LPF then most of the IR light will be blocked by filter thus the result will be insufficient. That's why the relation between the wavelengths of the filter and the IR source are so important.

- Soldering Equipment and some conductive cables
- Aluminum "U" profiles x 4 as a frame and holder for IR LEDs
- Enough rubber to prevent leakage of light between U profile and plexiglass.
- Tracing paper with silicone rubber as a compliant surface and rear projection
- A video projector
- Wood and other materials to prepare the case and the final look of *SquaTouch*
- Drill and a drill head in the size of the chosen IR head.
- Sandpapers at the scales of 100,400 and 600.
- Drill head for rubber and polisher (Also known as Brassco).
- Cold silicon containing Solvent for the preparation of the Compliant Surface
- Touline/Toluene or Xylol for thinning process of cold silicon
- Painting roller made of sponge for applying the prepared mixture to the surface with a textured surface

4.3.1.1 Plexiglass

Touch surface of the *Squatouch* is made of a 0.8 cm plexiglass. Considering the resolution of the computers and the standard projectors, plexiglass is sized in 4:3 aspect ratio standards. The most important reason why it is chosen as the material is that the IR light can propagate inside. This is not possible by using a normal glass. The application method of the FTIR technique makes plexiglass the only industrial alternative for now.

Because the IR light is applied from the side surfaces of the plexiglass, side surfaces have to be flat and smooth as much as possible. For this reason, sand papers of three different scales are applied on side surfaces (Figure 14).

First, 600 scaled sandpaper is applied to all 4 side surfaces. After that, same process is repeated with the 300 scaled sandpaper which has smaller bits. Finally, with the 100 scaled sandpaper the smallest possible surface gaps are flatted. The following process is polishing the side surfaces with a heavily intense material also known as polisage polisher in the industry. Polishing process is applied with a rubber drill (Figure 15-16). Here, an important case should be pointed out; without polished side surfaces the results would be unsatisfactory. Side surfaces are blurry even though they are cleaned with the sandpapers. However, after polishing there is a considerable difference in sharpness. That is why polishing is a must for the side surface.

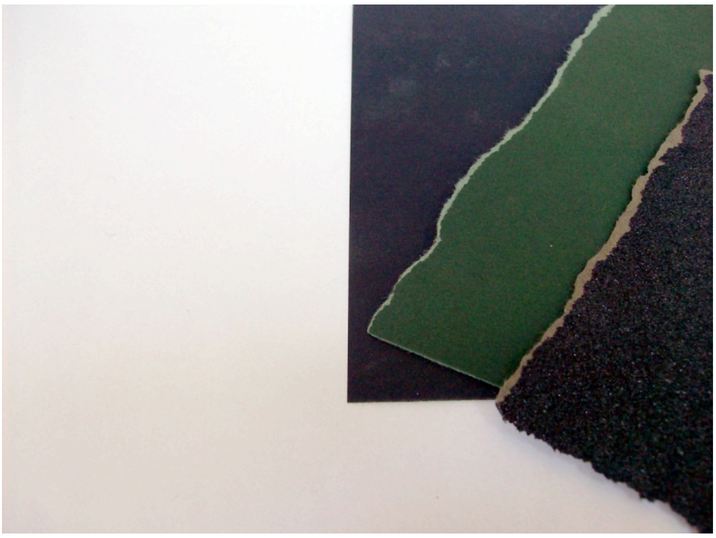

Figure 14. Sandpapers in three different scales

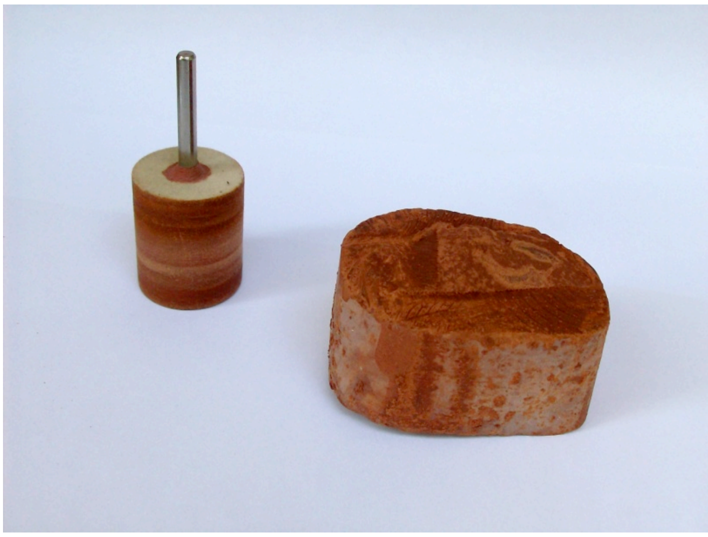

Figure 15. Rubber for driller and polisage polisher

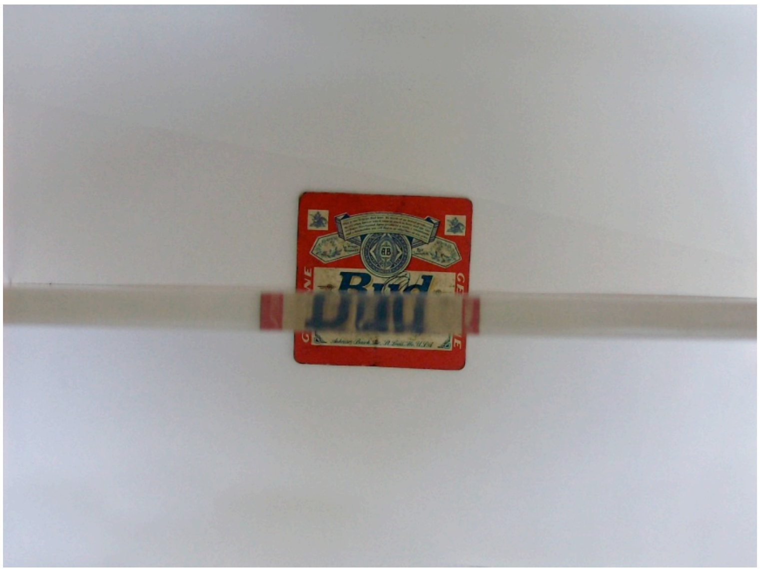

Figure 16. Polished plexiglass side surface

4.3.1.2 IR Leds and Led Array

IR light should propagate evenly and be intense enough inside the plexiglass for the cam to accurately follow the touched spot. Thus, the IR light source is also important.

Usually designers prefer 850nm or 940nm wavelengths for IR LEDs. Wavelength and the amount of light the LED radiates are inversely proportional. Thus, LED's irradiance gets higher as its wavelength gets lower. Also the amounts of the forward voltage and forward current affect the IR LED's irradiance.

For *Squatouch*, 64 IR LEDs are used; radiating at 940nm wavelength with a forward voltage value of 1.6 V and forward current value of 200 mA. To supply IR LEDs, a DC power supply of 1600mA at 12 Volt is used. The distance between LEDs is kept equal- 5cm- to distribute IR light proportionally. The LEDs are assembled into the holes on the aluminum U profiles.

To equally distribute the main voltage to the LEDs, a 27 ohm resistor connected 10 series of 6 LEDs is used. For the remaining 4 LEDs, a series with a 56ohm resistor is built (Figure 17). The circuit diagram for the LEDs is created by the LED Wizard[37] application, which can be used via Internet. LEDs on the U profile have been soldered according to this diagram (Figure 18).

[37] http://LED.linear1.org/LED.wiz

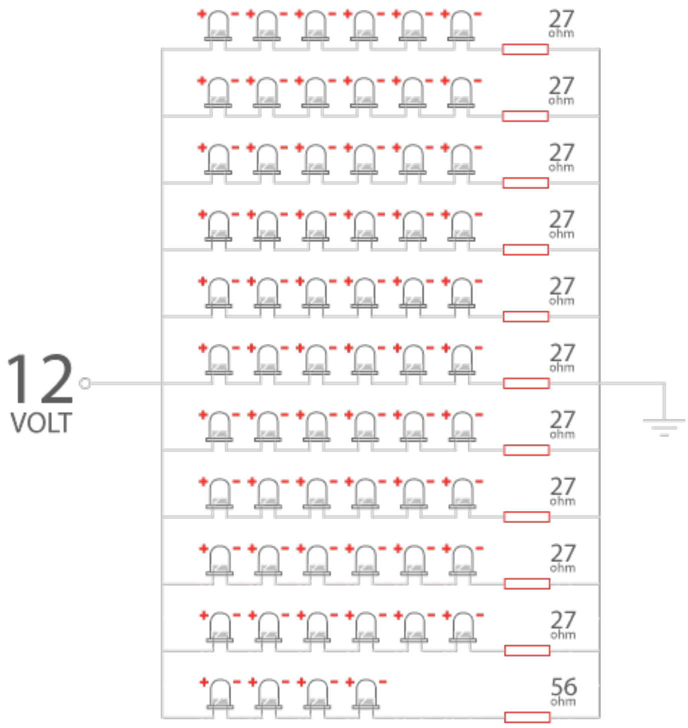

Figure 17. LED Wiring Schematics

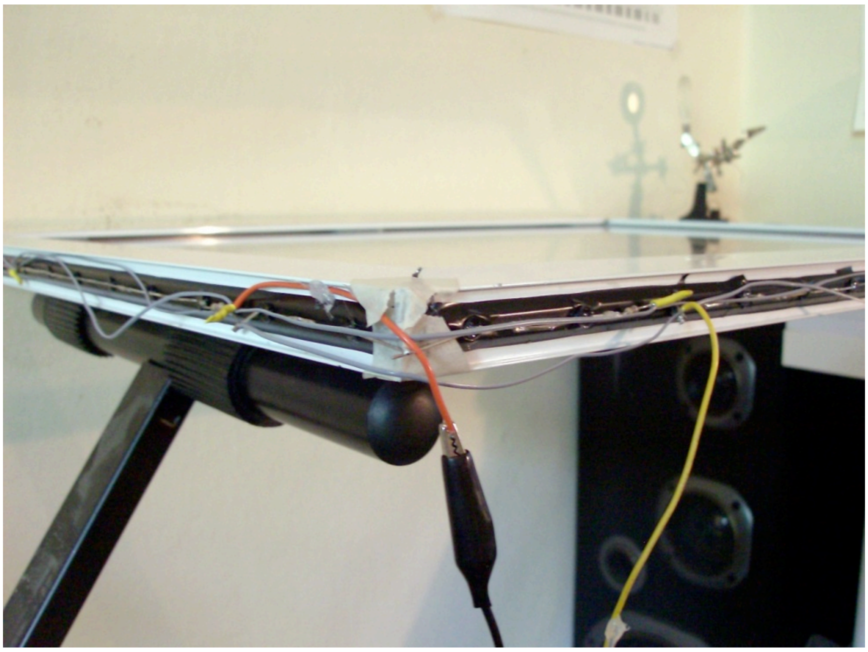

Figure 18. Assembled IR Leds to aluminums U profiles

4.3.1.3 The Camera & IR Filter

The camera has to detect sufficient IR light to track the print made by finger touch on the surface.

Ordinary cameras (both for video and photography) can also detect IR light, however it is not sufficient. Because, major part of the light is absorbed by the 'IR Blocking Filter' in front of the camera. Thus, the production of insufficient blob prevents to track the contact points on the surface. Therefore, it is necessary to change the High Pass Filter that blocks the IR in the camera with a Low Pass Filter. The frequency of the IR light is lower than the visible light. When a Low Pass Filter used, the higher frequency visible light is eliminated, hence, the camera can detect lower frequency IR light. Thus, the blobs produced by touching on the surface become easier to spot, providing the system to even work efficiently in dark.

There are also many alternative methods for the appropriate Low Pass Filter. For example a 35mm film negative or the material used for keeping data inside the floppy disks can also be used to block visible light while letting IR light in. Yet, they do not give effective results. The low power outputs of the LEDs that are used for this project as well have negative effect on this issue. However, some designers offer examples of successful applications of 3-4 layers of 35mm negative films as IR filters used by more powerful 850nm LEDs. Although the results seem satisfactory, desired result cannot be accomplished by using neither 35mm film negative nor floppy disks for *Squatouch*.

For this project a plastic filter dismantled from an old TV remote is used as a Low Pass Filter (Figure 19). After many tests, the most efficient result is gathered this way.

4.3.1.4 The Projector

For the users, one of the most important parts of the multi-touch physical interface is the projector. The projector is used for the projection of visual feedback on the plexiglass. This way, the user can see the touched area and the visual feedback on the surface simultaneously. This is one of the most important components ensuring direct interaction.

The projector used on this project is a standard 4:3 aspect ratio 3M projector.

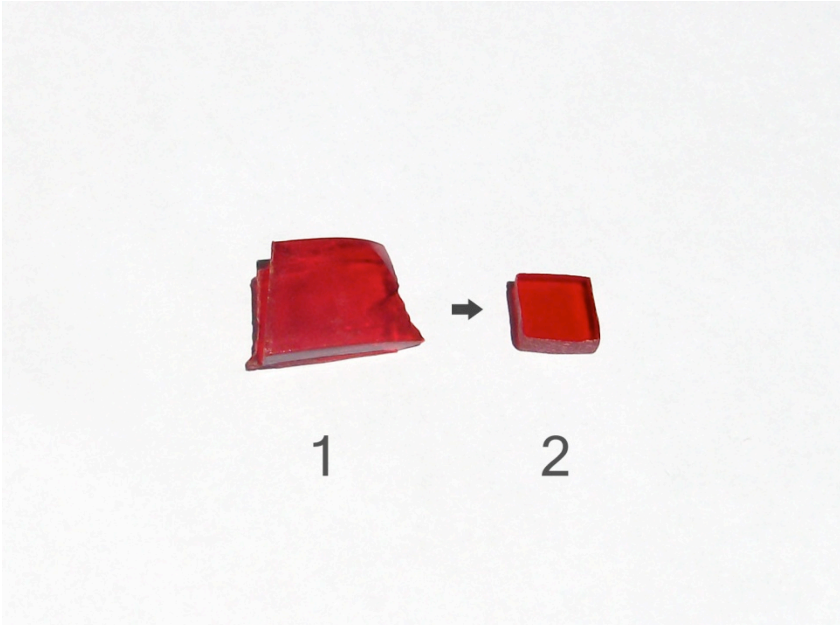

Figure 19. TV remote’s plastic piece (1), it has been shaped to fit in camera (2).

4.3.1.5 Rear Projection and Compliant Surface

The plexiglass is transparent, letting the light pass; it is almost impossible to see the projected image on the surface. This is why there is a need for a projection surface to catch the projected image. Because the images are projected from behind the surface unlike the conventional methods, the surface should also be semi-transparent. For this kind of application there are Rear Projection Surfaces on the market. However, to lower the cost and to introduce cheaper alternatives, many different cheap materials is tried out to find an alternative solution.

From this point of view, both Tracing paper and sketch paper accomplished the same job with an acceptable quality. But when the projection surface is positioned between plexiglass and the user, the camera is not able to detect any touch points. This is because the surface blocks the area the hand touches. Thus, IR light keeps propagating inside the plexiglass without any refraction.

To overcome this problem, a mixture is prepared from toluene and silicon, and then placed onto touch surface (Figure 20). After that, mixture is poured onto tracing paper and spread with sponge roller equally. Sponge roller (Figure 21) helps to create a textured surface. A textured compliant layer (Figure 22) couples with touch surface better as well. Textured surface of compliant layer should be contacted with plexiglass surface, not with the user's fingers. Otherwise, compliant surface cannot transfer the user's touch events to plexiglass. Consequently, blobs can not be created as expected.

Figure 20. Cold silicon is thinned with toluene.

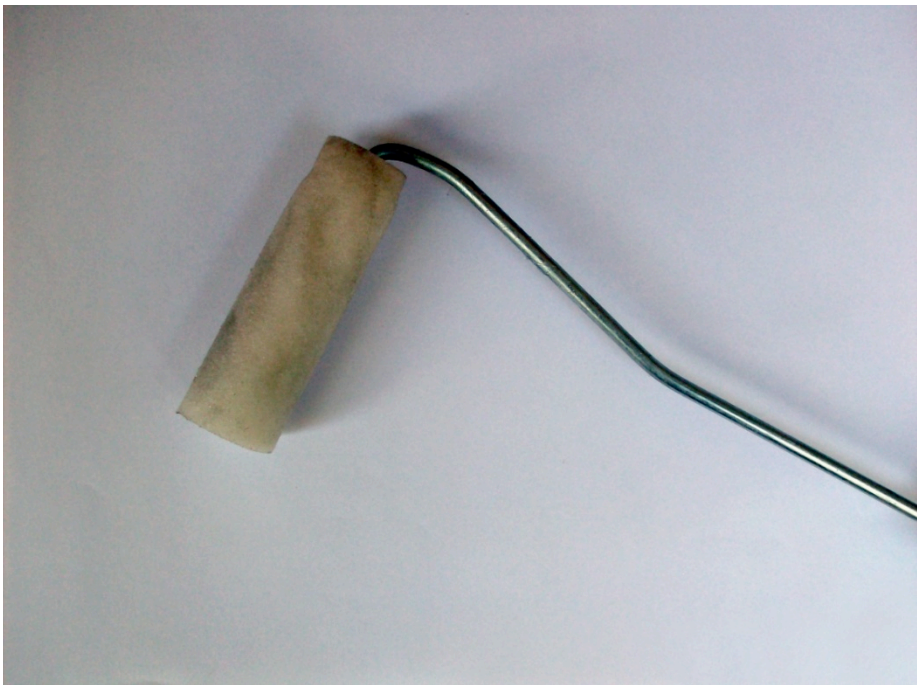

Figure 21. Desired textured surface could not be achieved with other types of rollers.

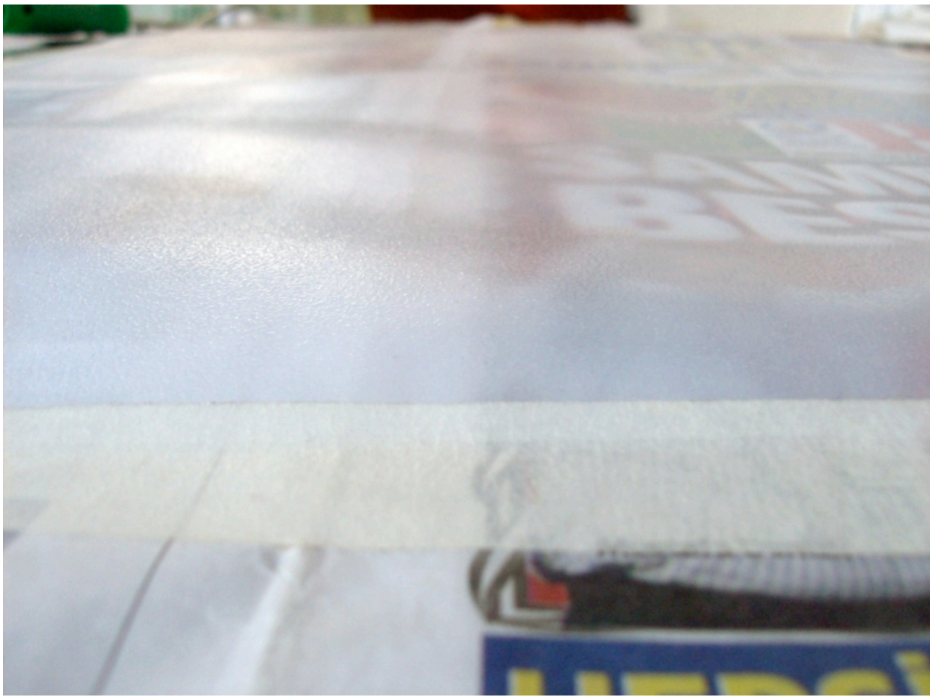

Figure 22. Compliant surface layer on tracing paper

4.3.2 The Software and Interaction Language

There are two main computer applications to create a touch based interaction language for *Squatouch: Tangible Musical Interface*. One of these applications is Computer Core Vision[38] (CCV), which gathers data of blobs' coordinates (x, y), blobs' distances from each other (dx, dy) and blobs' sizes. At the same time, CCV provides a calibration feature within its image processing filters (Figure 23). Another useful feature of CCV is that it outputs tracking data (e.g. coordinates and blob size) and touch events to other softwares via open sound control[39] (OSC) protocol (Çetin, et al., 2009). Max5

[38] "Community Core Vision, CCV for short, and formerly tBeta, is a open source/cross-platform solution for computer vision and multi-touch sensing. It takes a video input stream and outputs tracking data (e.g. coordinates and blob size) and touch events (e.g. finger down, moved and released) that are used in building multitouch applications. CCV can interface with various web cameras and video devices as well as connect to various TUIO/OSC enabled applications and supports many multitouch lighting techniques including: FTIR, DI, DSI, and LLP with expansion planned for the future (custom modules/filters)" (Çetin, et al., 2009 p. 60).

[39] "Open Sound Control (OSC) is a protocol for communication among computers, sound synthesizers, and other multimedia devices that is optimized for modern networking technology. Bringing the benefits of modern networking technology to the world of electronic musical instruments, OSC's advantages include interoperability, accuracy, flexibility, and enhanced organization and documentation." (CNMAT)

can receive and process OSC messages as well. Thereby, Max5 and CCV communicate with each other over OSC protocol.

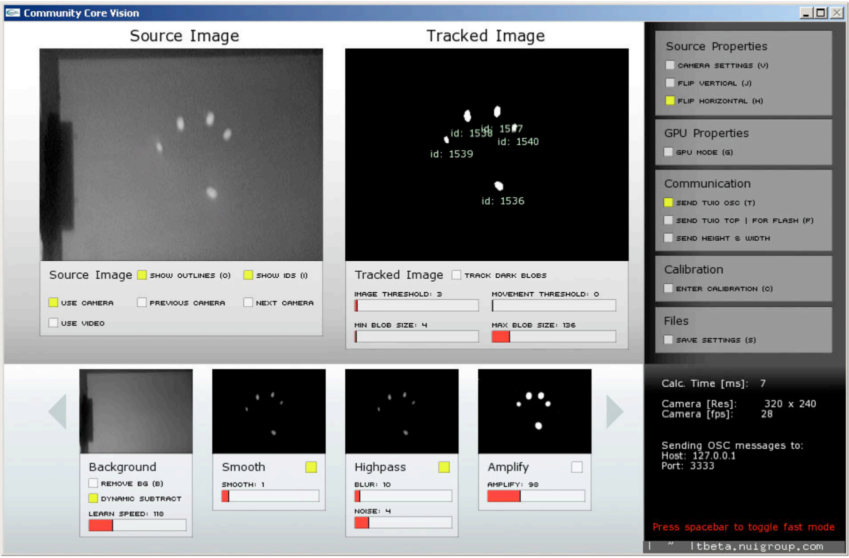

Figure 23. Screenshot from CCV blob tracker

Musical interface and programming of *Squatouch* is done within Max5 visual programming environment. Max5 is a graphical programming environment for developing real-time music systems. The underlying metaphor of Max graphics and control is taken from analog synthesizers (Balaban, et al., 1999). Max5 has various benefits for designers compared to other text based programming languages. Main commands and functions are represented as pictograms in Max5. Besides, Max5 has 'patch chord' feature which enables communication between separate objects. For example, there is a Max5 patch, which contains an oscillator, a number box that shows frequency and a digital to analog converter as shown in Figure 24. The computation is based on message passing along the lines that connect boxes. The patches correspond to processes that fire each other along the lines connecting their boxes (Balaban, et al., 1999). Text based representation of Max5 patch in Figure 24 is as follows;


```
{
"boxes" : [      {
        "box" :          {
            "maxclass" : "ezdac~",
            "numinlets" : 2,
            "patching_rect" : [ 279.0, 263.0, 45.0, 45.0 ],
            "numoutlets" : 0,
```

```
            "id" : "obj-4"
         }

      }
,        {
         "box" :          {
            "maxclass" : "number",
            "fontsize" : 12.0,
            "numinlets" : 1,
            "patching_rect" : [ 279.0, 134.0, 50.0, 20.0 ],
            "numoutlets" : 2,
            "outlettype" : [ "int", "bang" ],
            "fontname" : "Arial",
            "id" : "obj-3"
         }

      }
,        {
         "box" :          {
            "maxclass" : "newobj",
            "text" : "cycle~",
            "fontsize" : 12.0,
            "numinlets" : 2,
            "patching_rect" : [ 279.0, 183.0, 45.0, 20.0 ],
            "numoutlets" : 1,
            "outlettype" : [ "signal" ],
            "fontname" : "Arial",
            "id" : "obj-1"
         }

      }
 ],
"lines" : [       {
         "patchline" :          {
            "source" : [ "obj-1", 0 ],
            "destination" : [ "obj-4", 1 ],
            "hidden" : 0,
            "midpoints" : [  ]
         }

      }
,        {
         "patchline" :          {
            "source" : [ "obj-1", 0 ],
            "destination" : [ "obj-4", 0 ],
            "hidden" : 0,
            "midpoints" : [  ]
         }

      }
```

```
,       {
        "patchline" :           {
            "source" : [ "obj-3", 0 ],
            "destination" : [ "obj-1", 0 ],
            "hidden" : 0,
            "midpoints" : [  ]
        }

    }
 ]
}
```


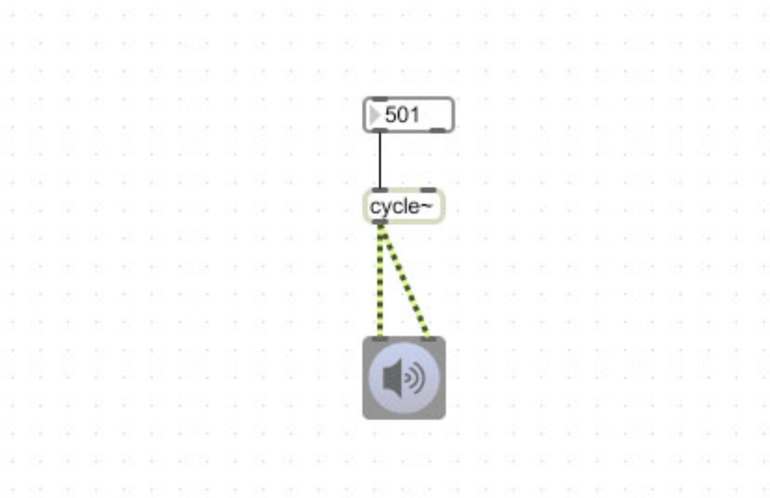

Figure 24. Basic signal generator patch that build in Max5.

As seen in Figure 24, graphical programming feature of Max5 makes it easy to understand the working principle and the sequence of the program for the end user.

4.4 Squatouch Musical Interface

Squatouch proposes a new interaction language that is based on hand gestures made while touching on the multi-touch surface. Although multitouch screen technology exists in many fields of life, there are only a few musical interfaces based on multi-touch screen technology. Therefore, a musical interface is developed for the multi-touch screens as a result of this project.

There are two main sections in *Squatouch* interface to benefit completely from multi-touch technology's new interaction language and opportunities. These are 'touch' and ‘mix’ sections. In ‘touch’ section, there is a control interface, which consists of a total of sixty-four squares and related parametric variables (Figure 25).

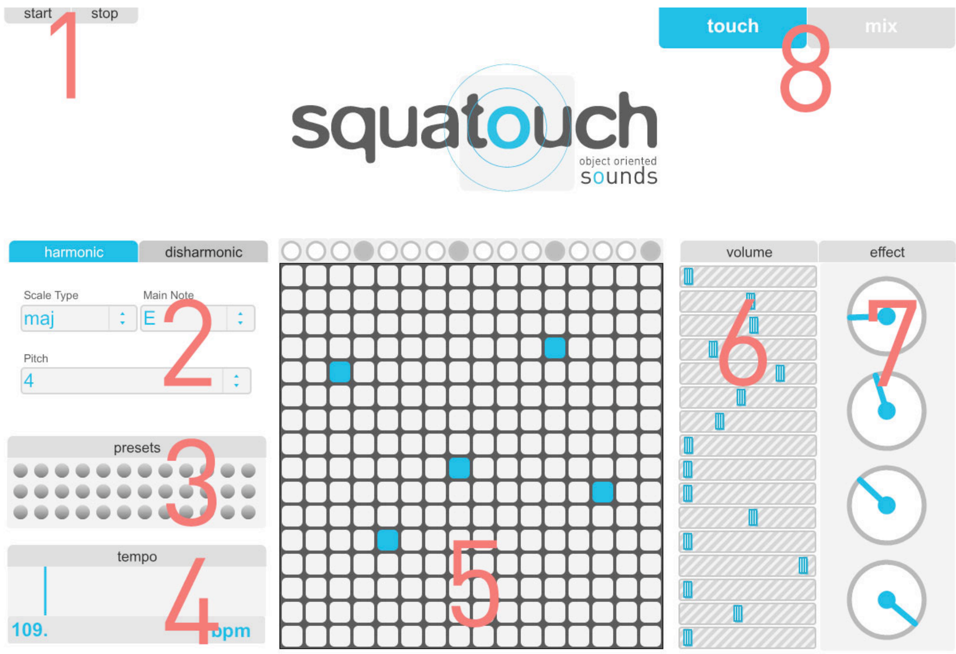

Figure 25. User interface of Squatouch.

When the application is started firstly, the interface in Figure 24 is displayed on the screen. Section 1 activates sound synthesis and sound editing process, and then it starts the application. When the user touches ‘start’ button, indicators move on horizontal plane in sequence at Section 5. The user can compose sounds by touching onto 16x16 matrix (Section 5). In ‘harmonic’ mode, frequencies (musical notes) are derived from one single note. The only thing that the user has to do in order to get sound from *Squatouch* interface is to select a desired tone and a scale type from Section 2. Remaining 63 squares of notes are generated by the program automatically. This structure of *Squatouch* is developed with Object Oriented Programming (OOP) language. One of the early and best examples of OOP is Sutherland’s *Sketchpad, which* was mentioned earlier in Chapter 2. Sutherland can create same image on *Sketchpad* consecutively without drawing it again and again. It achieves this operation with ‘class’ based programming language. Basically, the first image is kept in computer’s memory (library) as a ‘class’ object and when the user wants to draw same image onto the screen, he/she basically calls this class. Thus, the same image can be created as a copy (instance) of the main class object with a different instance name. For example, there is a program to calculate distances from a starting point for three cars with constant speed values. The code of the program is as follows;

```
variable car1speed = 100;
variable car2speed = 200;
variable car3speed = 300;
...
```

If a programmer needs to change these speed values, it will not be too difficult or time consuming. However, it takes too much time to edit the code structure in case the number of the cars is changed from 3 to 1000. To overcome this problem, the programmer should code the program in OOP structure as follows;

```
variable speed = 100;
for (i = 1 ; i < 1001; i++)
{
    carSpeed[i] = speed * i;
}
```

Along with OOP structure of the same program, all the cars' speed can be calculated with 'for' loop according to a global speed variable instead of writing the whole speed values one by one. So, the programmer only modifies the global speed variable in case the speed of cars needs to be changed. When global speed variable is modified, the program sets speed values of 1000 cars automatically.

Pitch values of notes shifts in vertical order and being fixed on horizontal order in Section 5. The user can select 'disharmonic' mode to compose his/her desired notes freely from Section 3. In 'disharmonic' mode, the user can select four different notes and a pitch value from the menus (Figure 26) and the remaining 60 squares of notes are generated by *Squatouch*'s OOP structure automatically.

In section 5, pitches are transposing to an upper value at every 4^{th} square from down to up. This means, on every 4^{th} square, notes are repeating themselves from an upper pitch value. The aim of this kind of placement is to provide harmonic richness for the user.

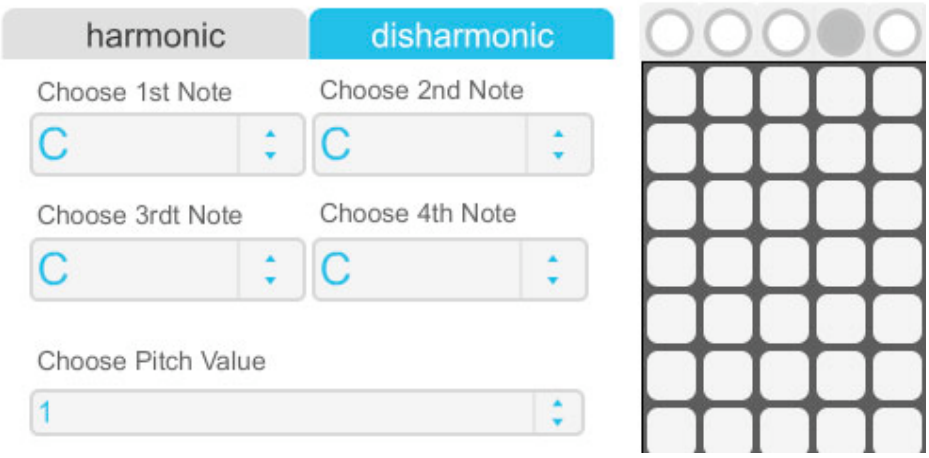

Figure 26. Squatouch ‘disharmonic’ mode

In Section 3, there is a preset manager for the user that allows for changing the whole setup immediately. Preset manager has various setup options by default. However, the user can rewrite these presets in whatever way he/she prefers. Preset manager is very useful when the user needs to change the whole setup rapidly.

In Section 4, there is a slider in order to adjust the tempo value of the music. Tempo value is set to 120 bpm by default.

In Section 6, there are sixteen gain sliders for every single musical note. The user can set the volume level for each note row dynamically.

In Section 7, there are four potentiometers to manipulate the sound of the four main notes.

‘Touch’ section of *Squatouch* is no more different than a traditional sequencer software interface, but its interaction techniques are totally different. Such an interface can also be controlled via computer mouse. However, computer mouse does not allow the user to interact with several control points at once. Besides, the user can interact with the things he/she sees at the display. In this respect, *Squatouch* interface turns out to be a more dynamic environment than the traditional computer systems. The main reason for this dynamism is that many of the parameters are being controlled just as they are in the real world. The user can push a button or turn a potentiometer virtually, but the gestures are very much like the physical ones. Therefore, communication language with multi-touch technology becomes easier than the traditional computer system interfaces.

Interaction language of *Squatouch* is a bit different in the 'mix' section. A direct interaction opportunity with sound is presented to the user in 'mix' section. At some respect, *Squatouch* makes it possible to touch sound as an abstract concept for the user. The 'mix' section allows user to edit, zoom in/out and apply effects to the visual forms of sound just like Adobe Photoshop (Figure 27).

Figure 27. Squatouch 'mix' section.

There are not only touch events in this section, but also gestural interaction styles. For instance, after touching onto 'zoom' button, the user can zoom in or out of visual form of sound by moving his/her fingers in opposite directions. Besides that, the user can fit visual form of sound resolution to an additional space by touching onto visual form of sound (pinching) with 3 fingers. The potentiometers in the 'mix' section require same interaction technique as in the 'touch' section. All of these gesture based interaction techniques are almost standard for multi-touch screens and experienced by many people. Gestural interaction language is not as complex as in digital watch example explained in Chapter 1. Because, the language of these gestures are somehow arbitrary as Donald Norman cited in his book (Norman, 2002). Norman calls this situation as 'mapping'. For example, when one pulls a rubber band in opposite directions, it lengthens. In this sense, the user can predict that when he/she moves his/her fingers in opposite directions, the width of the visual form of sound lengthen. Namely, gestural interaction language is based on similar perception forms and habits in real world. This is a factor that makes it easy to learn this new interaction language for the user.

CONCLUSION

Computer technology appears in all the areas of our daily lives today. It became almost impossible to live without computers. Computer interfaces that were developed on desktop concept offer many more opportunities today when compared to 1950s. However, each technological development requires a new communication and interaction language. Required language has taken a new form depending on many factors throughout history of the computer systems. In this sense, sometimes society shapes technology, and some other times technology leads the community. At this respect, it is impossible to express the change on the society and the technology with a unilateral causality.

Almost half a century has passed from the invention of the computer mouse. In the 1960s, computer mouse has moved human-computer interaction to a completely different level. It made the use of computers possible for ordinary people who do not have engineering background. Today, human-computer interaction techniques are being reshaped again. The increasing necessities require new technological developments. Computer mouse and keyboard based interaction language cannot meet the needs of people adequately. Computers' processing capabilities are not as low as in the 60's and computers can operate on several applications simultaneously. Increasing processing power of computers allows for running more functions. However, collection of functions around a single computer mouse makes the interaction language inefficient. The clearest examples for that are MIDI based control interfaces, which are developed for musicians, or graphic tablets, which are developed for painters that have emerged because of the lack of sufficiency.

In the last few years, multi-touch screen technology has become widespread and has carried human-computer interaction to different levels. Most importantly, rather than acting solely as a means of displaying an image of reality, the screen became a vehicle for directly affecting reality. Thus, real-time screen has become interactive (Manovich, 2001). Multi-touch technology allows the user to interact with information directly within his/her hands.

Squatouch: Tangible Musical Interface allows user gestural interaction with computer based musical interface instead of the computer mouse and the keyboard. In response to this proposal, what *Squatouch* expects from the user is to develop a new interaction/communication language. The developed interaction language that is used today generally with multi-touch screens has become the standard gesture form. From this perspective, it is much easier for the user to learn this interaction language.

Technology is in a continuous development. On the one hand, this innovation is guided by society; on the other hand it is driven by the market. However, each new technology brings along the necessity of learning a new interaction/communication language. Technology will be used as highly efficient based on how natural this language is. Naturalness does not mean a simple and less functional interface. In this sense, the offered interaction method and communication language by *Squatouch* is understandable and easy to use.

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