# He@rt and Software

## Product Report

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## Abstract

**Background:** The movement in art history concerning the interplay of technology and art can be traced back to the 1960s and 1970s. As technology tend to get old after some time and art does not, a challenge exists as to how art can give life back to the once so useful technology and how the technology can aid the visionary idea of the artwork.

**Purpose:** The main purpose of this project is to reuse the preexisting hardware and software by using the form of an Open Digital Canvas product. Our contractor was Letizia Jaccheri.

**Material and Methods:** One hundred sixteen circuit boards with LEDs attached were available as well as a pc, switches and Ethernet and power cables. A decision was made to mount the boards on the wall**.** We developed an idea to display an electrocardiogram wave (ECG wave) propagating along the wall, ideally including possibilities for interaction. Information was collected on relevant former artworks, ECG and LEDs. The wall was mounted in co-operation with two other groups and flash software was used to visualize an ECG wave on the wall.

**Results:** The wall was successfully mounted and our idea was displayed on the wall, excluding the interaction part. Our mounting of the wall benefited substantially from contributions from two other groups that had also chosen the same project.

**Limitations:** The duration of three weeks for the project limited the complexity of possible ideas and solutions. We also were up to co-operate with the two other groups, restricting us to agree upon a common physical frame.

**Conclusions:** A product was successfully made that displayed our idea. The product was interpreted from the viewpoint of each of our professions. Future implications include the possibility to develop the interaction part of the idea further.

## Contents

# 1. Introduction

The definition and description of the product, as well as the main purpose and goal, are summarized in this section.

### *1.1 Definition and description of the Project*

By combining the concept of art and software, a wall will be decorated and designed. One hundred sixteen circuit boards with LEDs attached were available as well as a pc, switches and Ethernet and power cables. The LEDs formed a matrix of pixels, in which the resolution is intentionally kept low as compared to what present technology can offer. This will make visualization on the wall an artistic challenge.

The idea that the group finally agreed upon, was to have an electrocardiogram wave (ECG wave) propagating along the screen on the wall. Our original idea was to be able to set up an interaction between the screen and the people using the room.

### *1.2 Aim of the project*

The idea of the project is to reuse the given ‘old-fashioned’ software and create art out of it. Our goal is to explore how the wall in a room can interact with people using that room, in an artistic and meaningful way. Can art make the discarded technology useful again, and can the old technology aid the visionary idea of an artwork?

## 2. Preliminary Studies

Throughout art history, several artists have been inspired by new technology in their time, and have been creating works of art that in general utilize the available technology in a highly experimental and visionary way.

### *2.1 What has been done before?*

The American artist Robert Rauschenberg is one of many that, early on in art history, explored the connection of technology and art in collaboration with electronic engineer Billy Kluver [1], particularly through his piece called 'Open Score'. This was a performance piece that took place in New York in 1966 held in the Sixty-Ninth Regiment Armory building. Around 500 hundred volunteers were gathered in darkness, all while they had been instructed to do simple gestures, which was recorded by infrared cameras and projected onto three large screens. At the same time, a tennis match was being performed, with radio transmitting rackets (Fig. 2.1 and 2.2). This was what the audiences saw and heard, because when the lights turned on, all the performers were gone.

**Fig. 2.1. Robert Rauschenberg, «Open Score», 1966**

Wired Tennis Racket | Photography | © ;

Rauschenberg's «Open Score» was performed on the second and ninth of «9 Evenings» in 1966 (October 14 and 23). This racket was made for use in «an authentic tennis game with rackets wired for transmission of sound»

**Fig. 2.2. Robert Rauschenberg, «Open Score», 1966**
Photography | © ;

This performance piece shows an early interest in both working with new technology in an experimental way, but also a dedication to collaborate across different fields of interest. This is relevant to the project ‘Heart and Software’, where the aim has been to create an artwork using software (new technology) despite differences in education, using each individual skill to its fullest potential.

The ‘Open Score’ project also reflects how conceptualism has influenced artist’s work before and after the 1950’s, where the process is more important than the actual output. French artist Marcel Duchamp [2], often associated with the Dada movement[1] [3], has partly been credited by many art critics to be the father of conceptualism, beginning in the early 20th century. In 1915 he began making his “readymades” - found objects that he chose and presented as art. A few examples are his ‘Bicycle Wheel’ and ‘Fountain’ (Fig. 2.3 and 2.4).

[1] **Dada** or **Dadaism** is a cultural movement that began in neutral Zürich, Switzerland, during World War I and peaked from 1916 to 1920. The movement primarily involved visual arts, literature (poetry, art manifestoes, art theory), theatre, and graphic design, and concentrated its anti war politic through a rejection of the prevailing standards in art through anti-art cultural works. Dada activities included public gatherings, demonstrations, and publication of art/literary journals. Passionate coverage of art, politics, and culture filled their publications. The movement influenced later styles, Avant-garde and Downtown music movements, and groups including Surrealism, Nouveau Réalisme, Pop Art and Fluxus.

**Fig. 2.3.** Bicycle Wheel by Marcel Duchamp, 1913

**Fig. 2.4**. Fountain by Marcel Duchamp, 1917, photograph by Alfred Stieglitz.

Through these ready-mades he opened up a new way of looking at and creating art. He initiated and legitimized the use of everyday objects as justified materials along side with more conventional arts material such as paint, paper, wood, iron etc. The idea became more significant than the actual outcome or object. Conceptualism still reigns in today's contemporary art world, and is the basis for most contemporary artwork and especially in New Media.

Software and art is a relative new phenomenon that is developing rapidly, and new inventions are constantly being developed. From this point of view, questions arise such as whether software and hardware can be utilized when it is too 'old'? In many contemporary artist cases it can still be used, since in general the artist is more concerned with creating a project that involves a critical process, experimentations and conceptual possibilities and how to express this in a visual form, rather than thinking of an end product that can be profitable, which is the characteristics of the commercial industry. The Electron Club (www.electronclub.org) in Glasgow Scotland is an illustration of such interests as how to reuse old hardware in a new context. The club is organized by artists who are interested in new technology - programming, soldering, open software etc. - anyone who is interested can join and don't need an artistic background. One of their concerns is the waste generated by the rapid market of new goods, thus they investigate how to reuse old hardware to construct new works.

Digital art is not so much rooted in the academies but rather the military and file sharing among scientists. The computer was developed by scientists in the 1950's with no particular interest in the arts. As a result, the art generated on computers had not risen to a high level of artistic integrity, since the focus was more on developing technical aspects. "It is only at the end of the 1990's that the aesthetic bar has been raised in this art form" *[1]*.

It was first in the 1980's when the computer became more affordable and accessible to the artist and people in general, that digital art established an artistic integrity. The digital art also became more interactive, which required the involvement of the viewer; notable are the programmed light installations (Fig. 2.5) by the German artist Otto Piene [1].

**Fig. 2.5**. Olympic Rainbow, 1972.Light (including lasers) is controlled and manipulated by computers, as it once was by the artist on the canvas

Software based art has moved away from people's home via the personal computer and moved into the public space connecting with the surrounding architecture. Furthermore, the invention of the computer has freed art from the ‘object’ and digital art is very much connected with the term interactive. “In art, visual literacy is no longer limited to the ‘object’. It must embrace the fluid, ever-changing universe that exists inside the computer and the new world that can be virtual in its reality and radically interdependent in its incorporation of ‘the viewer’ into the completion of the work*” [1]*.

***2.2 How are the plates used in practical way?***

Some concerns arise in relation to interactive artworks and use of such in public spaces. Where is the border between entertainment and art? Has a particular invention just become another gadget to play with? One such example is the Dexia tower in Brussel, which has an interactive light installation created by LAb[au]. The windows of the tower have been outfitted with RGB LED bars (Fig. 2.6), which can flip on and off or change color at will. It can also be controlled by a series of touch screens at the base of the tower [4].

**Fig. 2.6**. copyrights* Pictures LAb[au]. Light Artist : LAb[au]

The system recognizes both static (touch) and dynamic (gesture) input to generate an elementary graphical lexicon of points, lines and surfaces. These are combined with physical, behavioral movements (growth, weight) and use a monochrome color palette (background) combined with black and white (graphics).

When drawing parallels to German artist Hans Peter Kuhn [5], who works with large scale light and sound installation in public spaces, immediate differences occur. “Pier 32 on the lower west side of Manhattan was the setting for the installation, ‘The Pier’. Nine five-meter tall towers, two meters by two meters in cross-section, were placed in a row along the 300 meter long pier. A loudspeaker was built into each tower; the sides of the tower were painted in different colors. At night each side was lit by floodlights in the same color. Sounds moved at high speed from tower to tower along the pier. The audience was on another pier, new pier, 120 meters away, parallel to Pier 32*” [5]*. First of all, his approach to activating the space through sound and space is based on a very considerate thinking process. He uses his artistic intelligence to create works that requires the imagination of the audience to interpret what they see and hear. His installations are not made to create an entertainment spectacle, as in the case of the Dexia tower, where the audience is neither required to ask questions about the space in which they embody, nor to trigger the imagination. They only need to receive and consummate imagery in an already overloaded world of visuals.

Finally, another contemporary artist worth mentioning, with the most relevance to ‘Heart and Software’, is the Finish artist Laura Beloff. She works with software and art and is also known for working with wearable - electronically objects that you can wear. A relevant project in relation to Heart and Software is her piece called ‘Heart Donor’ [6]. She has made a vest that contains all the necessary technology to make it mobile and independent, and enable it to move on the streets. This includes heartbeat recording interface, microcontroller, LED lights and bluetooth connection. The mobile phone fetches the real-time online data of the heart donors and uploads information about the vest onto a server for use on the website. After a certain amount of time, the vest needs to be recharged. The incorporated LED lamps in the vest are attached to a glove with sensor reacting to touch, measuring the heartbeat of people. One can collect up to 30 recordings of different people’s heart rate. The LED is defaulted to flash green, but flashes red whenever one of the people whose heart rate is stored goes online Skype (Fig. 2.7).

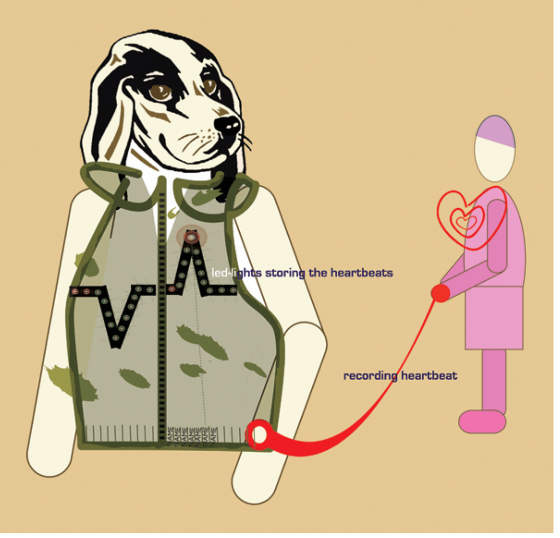


**Fig. 2.7.** Three illustrations of Jacket from Laura Beloff´s website

The artist says about her Heart donor piece: “The work attempts to make this fairly new concept of space we live in, visible and materially concrete, in contrast to common unnoticeability influenced by the ordinariness of mass-produced devices”.

This can be seen as a parallel to ‘Heart and Software’ where the artistic vision was to reconstruct the wall in a way that it became an interactive work resonating the people using the space, representing each individual by displaying an ECG image, and when entering the presumably electromagnetic field, it will show no activity. The idea is thought of as being a digital expansion of the room, traveling further into an imaginary world. Putting weight on developing a strong concept gave birth to this idea, rather than focusing on creating a visual spectacle.

### *2.3 Light Emitting Diode (LED)*

A LED is a semiconductor diode that emits light by using pn-junction, in a form of electroluminescence when the voltage is applied in the semiconductor. LEDs are used for indicator of lights in higher applications such as flashlights. The colors of the light depend on the materials used in the semiconductor, in which the color can be infrared, visible or ultraviolet.

Already in the early $20^{th}$ century, semiconductor junction was first found, in which it could produce light. In the mid 1920s, a Russian scientist invented the LED. However, his discovery was unfortunately ignored due to lack of technological progress. In 1955 Rubin Braunstein in the USA came up with an infrared emission from gallium arsenide and other semiconductor alloys, which found out to be giving off the infrared radiation. By using this radiation and light-emitting diode, they were able to develop the first practical visible-spectrum LED in 1962. LED became more in use in the end of 1960s. Thereafter, the first yellow LED and brighter red and red-orange LEDs were invented.

A Japanese scientist, Shuji Nakamura, showed the first blue LED, which led to the first white LED, by using the technique that applied $Y_3Al_5O_{12}$:Ce to mix yellow light with blue to produce light that emits white light.

LED is becoming more in use because it is more effective in saving energy than preexisting light source. The brightness of LED was limited in the beginning, but it has been improved and used in many practical markets. These days, because the cost of petroleum rises continuously and people are becoming more interested in less use of energy, people are concentrated on more use in LED and other practical products. It has been assumed that petroleum resource, which is mostly used as an energy source, has limitations after many years. Therefore, advanced countries have been trying to search for new energy sources. They were especially concentrated at the limited petroleum resource that can be used efficiently, and the long-lasting light-emitting sources. This is the reason why the markets for the LED industry have been increasing quickly.

### 2.3.1 What is LED?

**Figure 2.8. LED**

Basically, LED is said to be a junction between p- and n- figured semiconductor in which they form terminal electrodes, in which the current flows from p-side to n-side. When the voltage is given to these terminal electrodes, an electrical current is formed, which in turn creates light at the pn-junction. The color of the light emitted depends on the band gap energy of the materials forming the pn-junction. The origin of LED has begun already in the beginning of 1920s, when they demonstrated silicon carbide (SiC) as the first material that emitted light by a direct current. At that time the growth of SiC was difficult and it was hard to manage, therefore there was no progress using SiC. However, in 1952, it was first reported that the light was emitted from silicon and gallium (Ga) pn-junction semiconductor, and moreover, gallium phosphide (GaP) was used as a material creating orange light. The research on LED was taking place mostly in the 1960s, and mostly used semiconductor LED today was developed from Ga in 1962. In 1968, gallium arsenide phosphide (GaAsP), a semiconductor material that is an alloy of gallium arsenide and gallium phosphide, showed to produce red, orange and yellow LED. Infrared and red devices are first made with gallium arsenide.

By utilizing different materials it has been possible to create different colors of light. The mostly used material for commercial LEDs is GaN/InGaN and sapphire substrate. To increase the efficiency of LED, a substrate is used that is transparent to the emitted wavelength which can be reflected back by a reflective layer, and, second, the refractive index of the material should match the index of the semiconductor. If the refractive index of the material does not fit in the index of the semiconductor, the produced light is reflected back into the semiconductor, which can generate heat and in turn lower the efficiency of the LED. To reduce this inefficiency of LED, the reflected light is either reabsorbed and reemited, or a dome-shape package is used with the diode in the center so that the light rays can hit the surface with minimized reflection angle.

### 2.3.2 Organic Light-Emitting Diodes (OLEDs)

If the material that is used for LED is an organic compound, it is called an Organic Light Emitting Diode (OLED). OLED is lighter compared to LED and more flexible. Future applications of OLED can be: Inexpensive and flexible displays, light sources, wall decorations and luminous clothes. OLEDs are already in use in displays on portable electronic devices such as cell phones, digital cameras, and MP3 players.

### 2.3.3 Advantages using LED

One of the advantages of using the LEDs is that they save more energy compared to normal incandescent bulbs. Moreover, they can emit different colors of light without using other color filters, which lowers the costs. The LEDs can be designed to focus on it’s light while the normal incandescent source needs an external reflector to assemble light.

LEDs have longer lifetime, around 35,000 to 50,000 hours, which suit very well to frequent on-off cycling, than incandescent light bulbs which have only around 1000 - 2000 hours of lifetime. In addition, LEDs are unbreakable by external force unlike the normal incandescent bulbs. LEDs have fast response of lighting up, and they are easy to be placed onto printed circuit boards because of their variable sizes.

### 2.3.4 Disadvantages of using LED

On the other hand, LEDs can be inappropriate owing to a few reasons. One of the disadvantages of using LEDs, is that LEDs are dependent on the ambient temperature of the operating environment. High temperatures can affect overheating of the LED devices, which can result in device failure. Therefore, sufficient heat-sinking is required to maintain the long lifetime. Furthermore, LEDs can be more expensive on an initial capital cost than normal light devices. However, in December 2007, scientists in Glasgow University have found that LEDs can have brighter and use less energy than the light bulbs. There has been increasing concerns that blue- and white-LEDs might be able to exceed the limitation of the “blue-light hazard”, which is defined as the potential for a photochemical to cause retinal injury by radiation exposure. In addition, LEDs must have the correct current, which includes shunt resistors or regulated power supplies.

### 2.3.5 LED panels

Two types of LED panels, conventional using discrete LEDs and surface mounted device (SMD) panels, are used. The panel used the most for outdoor screens is conventional LEDs, which use red, green, and blue diodes to form a full-color pixel. The largest size of the LED is over 457.2 m long and is located in Las Vegas, Nevada. Indoor screens utilize SMD system on the market, where the SMD pixel consists of red, green, and blue diodes. SMD is a technology that constructs electronic circuits in which the components are installed onto the surface of printed circuit boards. Indoor screens generally use SMD technology and have a minimum brightness of 600 candelas (unit of luminous intensity, *nits*) for high ambient-brightness conditions such as fashion and auto shows. For outdoor use, at least 2000 nits are needed, and for higher brightness types need up to 5000 nits which are suitable for better visualizing light with direct sunlight [7].

## 3. Choice of Idea

When choosing our idea for the project, we agreed upon some criteria that we wanted to be fulfilled. First, we wanted to develop a concept that could benefit from the multidisciplinary competence in the team. Second, we would like our product to have a potential for future development. Finally, we wanted to come up with an idea that all people can relate to in some way.

### *3.1 Description of our Idea*

The idea of the project is to reconstruct the wall in a way that becomes an interactive work responding to the people who are using the space. The final idea that we settled for was to display an ECG wave propagating along the screen on the wall in the same manner as one would see it on an ECG monitor. We thought of the idea being a digital expansion of the room travelling into a digital world, creating a platform for further imaginary journeys.

Included in our original idea was to be able to create some form of interaction between the screen and the people using the room. If the system could monitor the sound level in the room, this level could be visualized by varying the distance between each ECG wave. When the sound level rises in the room, the distance between each wave could be made shorter to reflect this. A lower sound level, however, would result in the waves appearing wider apart from each other on the screen. This visualization effect could have a dual interpretation: It could in one sense reflect the noise level in the room. A second interpretation could be to reflect in medical terms, as a shorter distance between two consecutive ECG waves represents a faster heart rate. Each of these interpretations could make sense for the people in the room experiencing the screen, as a higher heart rate could reflect more hearts beating in the room, and of course the sound level in the room is in general a function of the number of people present. In short, we would be able to measure the ‘pulse of the room’.

Further, we wanted to expand the possibility for interaction with the wall by take into consideration an electromagnetic field located on the floor in the middle of the room. If we could install sensors reacting on movement in this zone, then if someone happens to step into this field, the ECG wave on the screen could suddenly turn flat, representing no heart beat. This could function as a kind of warning sign to help people in the room being aware of the field, and at the same time it promotes reflection on how radiation can affect living beings.

The ideas described above are what we would try to realize if we had not faced any limitations. However, considering the limited amount of time available and our tight budget and shortcomings when it comes to create suitable sensors to make the system work and run properly, we decided to limit our ambition and reduce the complexity of the idea in order to make the task more realistic, considering the frames of this course.

Therefore, we decided that the wall should display a propagating ECG wave starting from one end of the screen and continue to the other end. Then the wave would start all over again from the beginning, like it would be displayed on an ECG-monitor used in a hospital. The wave would alternate between showing a characteristic ECG wave and a flat ECG, each telling the story of the different aspects of our original idea.

## *3.2 Background on ECG*

This chapter starts with a short introduction on ECG and what type of information it provides. A historical view of the ECG technology will be given, and the ECG will then be interpreted from different points of view, hopefully encouraging further reflections and interpretations by the readers.

### 3.2.1 Description of how the wave is made and what it can tell us

In the nineteenth century, researchers noted that the muscles and the heart – which is a muscle itself – produced electrical activity. Different cardiac cells serve different and very specialized functions, but all are electrically active. The heart's electrical signal normally originates in a group of cells high in the right atrium that depolarize spontaneously; it then spreads throughout the heart from cell to cell. An *electrocardiogram* (ECG) gives us a way of recording the heart's electrical flow by placing electrodes on the surface of the body, creating one of the simplest and yet one of the most useful diagnostic tools available to the clinician [8].

In order to obtain a standard 12-lead ECG, one places two electrodes on the upper extremeties, two on the lower extremeties, and six on standard locations across the chest (Fig. 3.1). By combining these in different ways, the electrodes on the extremities generate the six **limb leads** (three standard and three augmented), and the chest electrodes produce the six **precordial leads**. In a lead, one electrode is treated as the positive side of a voltmeter and one or more electrodes as the negative side. So, a lead records the fluctuation in voltage difference between positive and negative electrodes. By varying which electrodes are positive and which are negative, the ECG machine records a standard 12-lead ECG. In this way, each lead looks at the heart from a unique angle and plane, having its own unique point of view [8].

**a)** **b)**

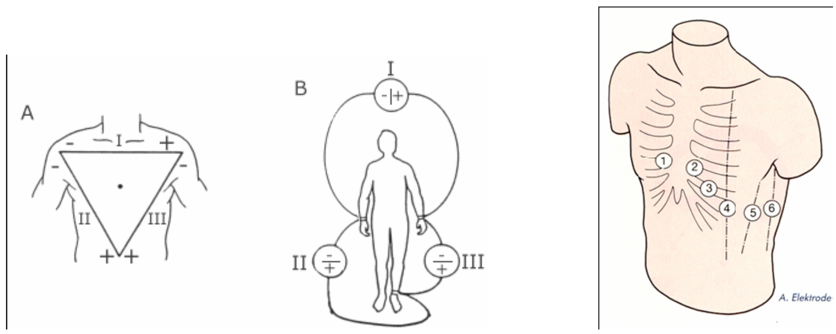


**Fig. 3.1**. Positioning of the electrodes on the body. **a)** How the electrodes are placed on the body (B) and combined to produce the limb leads and Einthoven's triangle (A). **b)** Locations for the six electrodes on the chest giving rise to the six precordial leads. Pictures are taken from Vik-Mo [9].

Conceptually, one can compare these 12 leads to 12 experts working in team, and the heart would be the model that all the experts would focus on from each of their unique point of view, that is, their own professional background. This analogy may help to get a better understanding of the standard ECG recording.

The fluctuations in extra-cellular voltage recorded by each lead are called waves, and they are named with the letters from the alphabet (Fig. 3.2):

- The P wave reflects depolarization of the right and left atrial muscle.
- The QRS complex represents depolarization of ventricular muscle.
- The T wave represents repolarization of both ventricles.

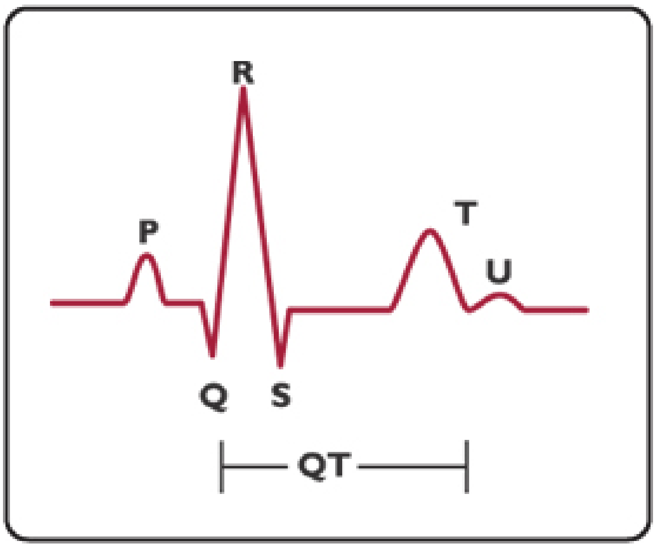


**Figure 3.2**. An ECG wave displaying the different deflections in the electrocardiogram.

The shape and magnitude of these waves are different in each lead, because each lead views the electrical activity of the heart from a unique point of view.

### 3.2.2 Historical Perspective

The ECG was invented by Dutch physiologist Willem Einthoven in 1902 and represented a major advance in the methods available for the diagnosis of heart disease. It also started a new era in which various machines and technical procedures gradually replaced the physician's senses and the stethoscope as the primary tools in cardiology [10]. Today, there is no denying the prominent role of technology in contemporary medical practice, and especially in cardiology.

The ECG has had an interesting developmental history, starting in the beginning of the 20$^{th}$ century with Einthoven publishing his recordings of the electrical cardiac cycle using a new device called the string galvanometer. The device used the standard frontal-plane limb leads, essentially today's limb leads. For three decades, physicians and researchers relied on the three limb leads Einthoven introduced in 1902. Whereas these leads were satisfactory for characterizing disturbances in heart rhythm, they proved inadequate for evaluating patients with other manifestations of heart disease. It was proposed that there were "silent areas" in the heart where infarction could occur but then would not be accompanied by abnormalities in the three limb leads. Motivated by this, the six precordial chest leads were introduced by the 1930's. The 12-lead electrocardiogram as we know it today resulted from sequential discoveries and innovations, with the final lead configuration adopted for routine use being completed in 1942, when the three augmented limb leads were introduced [10]. Despite significant advances in cardiology, little further development of the 12-lead ECG has occurred since 1942 except for the occasional use of additional leads in association with the 12-lead ECG [11].

One can therefore argue that ECG is an old technology, and it has survived and is still of vital importance because of its significant contribution to cardiac diagnosis and management. The basic principles and technology remain the same, as well as the shape of the ECG waves and the interpretation of them. A search in the medical literature revealed papers reflecting on the 12-lead ECG and arguing that another setup of electrodes or the addition of body surface mapping would make it possible in some cases to detect heart disease located in electrocardiographically "silent" areas of the heart – that is, areas that none of the 12 leads in the traditional ECG can see. Using our analogy, this would be like adding more experts to the team, making it possible to see the problem from additional points of view. For example, William J. Brady in 2007 made an analogy between the ECG having 12 leads and the belief from the time of Middle Age that the earth was flat [11]. This frustration in some parts of the medical profession reflects the strong presence and impact of ECG in medicine and that it has been present essentially unchanged for a long time. Just like the circuit boards with the widespread LEDs that we have been working with, the ECG can in a way be looked upon as an "old" technology that still has been found useful. Why is this so? Is it because the field of ECG and the interpretation of it has become an art in some way? Or has it just showed to be too difficult to change? Harald Vik-Mo, professor in cardiology at Norwegian University of Science and Technology and St. Olavs University Hospital, once stated in a lecture to his medical students that if someone were to change how the ECG has been standardized and alter the field of ECG, they would probably have to spend their whole professional career in doing so, and do nothing else. The ECG is as such an example of an "old" technology that has survived for a very long time, and the ECG wave has become a recognizable wave far beyond the medical profession, in a sense in the same manner as the way in which world famous art becomes a part of the world's heritage and our common consciousness. The wave can for example be displayed on stamps or in movies without any further explanation, like when the Kingdom of Konga released a set of stamps to commemorate 30 years of membership of the Commonwealth and one of the stamp's design included medicine, surgery, nursing, and, in the background, the electrocardiogram [12].

### 3.2.3 ECG and software

Development of computer analysis of electrocardiograms can be traced back to the early 1960s [10]. When introduced into clinical practice in the late 1970s, these computer techniques changed the way cardiologists interpreted electrocardiograms. The interpretation done by the computer is checked and revised as necessary by a cardiologist. In a way this has contributed to a decline of clinical electrocardiography, as there is a risk that only those ECGs which are recognized by the computer as being abnormal, are being read and interpreted by the physician. But can the interpretation of an ECG recording be done by a computer? Or is the skill of ECG interpretation some kind of art that that cannot easily be replaced by an algorithm? According to Shah et al [13] more than 100 million computer-interpreted electrocardiograms (ECG-C) are obtained annually. Their study from 2007 determined the accuracy Of ECG-C rhythm interpretation in a typical patient population, and it was found that the ECG-C demonstrates frequent errors in the interpretation of nonsinus rhythms. Thus, expert overreading of the ECG remains important according to this study. Charles Fisch supports this conclusion [14], stating that the programs lack accuracy and reproducibility. He further suggests that because of the availability of computer interpretation, the intellectual processes necessary to arrive at an ECG diagnosis are often circumvented and that the computer in fact may be an obstacle to the acquistition of ECG skills. While reasonably reliable for the analysis of the normal ECG and some abnormal ECG waveforms, not all ECGs can be programmed because of their complexity.

### 3.2.4 ECG and politics

The cost of health care is constantly an issue, and this also affects the use of ECG as a tool in diagnostics and management. An example is the effort from the American government in the beginning of the 1990s to sign a legislation that affected physicians who interpreted electrocardiograms. The Omnibus Budget Reconciliation Act of 1990 included a provision that eliminated separate reimbursement for the interpretation of electrocardiograms. Although a coalition of specialty societies tried to convince Congress that this was a mistake, George Bush vetoed the bill in 1992. In 1993, Bill Clinton restored separate payment for the interpretations of ECG. Had separate reimbursement not been restored, the test would probably have been performed less often in the future [10]. So, political issues can also have an impact on the usage of available technology, and sometimes it can be a political decision that determines whether a technology lives on or becomes “old”.

### 3.2.5 ECG and Sports

The choice to display an ECG wave on the wall has an exercise physiological aspect as well. ECG has many close relations to sports and exercise, and some of the symbolism with the wave is making the people looking at it to think in a physiological way.

The ECG is a commonly used tool in the world of sports and exercise. For instance, ECG has been used to detect different evolving of the heart of athletes, showing larger heart in endurance athletes than in average people [15]. Further, ECG is often used to test people for heart problems, which, if not detected, can lead to sudden cardiac death during heavily training, and according to Fuller *et. al* [16] ECG is a much more effective screening tool than the patients cardiac history in detecting abnormality in the heart before approval in sports are been given. As seen, the ECG wave has a direct relationship to the world of sports and exercise, but first of all it is a powerful symbol of the human heart which is the essence of all exercise and even life itself.

Many people work mostly with concrete and visible things, and do not offer much thought to what they cannot see, even though these things are important. One of these things is the human heart. Buried in the center of man, and covered in flesh and skin. It is totally hidden away for the human eye to see, but is still the most important factor for our bare existence. By revealing the wave of the heart on the monitor, the people who do not offer any thoughts on their hidden-away-heart, might, by looking at this concrete image, stop up for a moment and start thinking about their heart and maybe realize that the heart is an important part of them which they should take care of. This also symbolizes one of the aspects of the *veggidi* project; making something invisible visible.

The body functions rely on the heart’s ability to deliver blood, and thereby delivering oxygen and minerals together with removing waste products to/from the brain, the muscles, organs and tissue. The heart of an endurance average with 25% larger left ventricle volume than in untrained. An athlete’s large heart gives an increased capacity for delivering blood to the body. The increased cardiac output (CO) of an athlete is not due to an increase in the heart frequency (HF), but a product of many factors including the increased volume of the left ventricle, better filling of the heart, and greater contraction of the heart chambers, leading to more blood being pumped out of the heart, and increased venous return among other factors [15]. In a sub-maximal activity state this implies that the greater CO enables the heart to deliver enough blood to the body without increasing the HF. This, in turn, leads to an increased ability to maintain a lower HF at sub-maximal intensity, and thereby increasing the ability to keep the intensity for a prolonged time [17]. Further, this decrease in HF, combined with increased levels of blood pressure decreasing enzymes and dilatation (increased radius) of blood vessels, leads to a decrease in blood pressure.

More simplified, an athlete has a lower blood pressure and is able to maintain higher intensity for a prolonged time compared to an untrained person, and at the same time has a greater maximal capacity, as the heart of an untrained is able to pump 20-25 $L*min^{-1}$, while the heart of an athlete is able to pump as much as 40 $L*min^{-1}$ [15].

Many people, especially overweight and people middle aged and older, which is likely to include a great part of the people using the meeting room, are at risk of getting high cholesterol levels. There are two different kinds of cholesterol. These are Low Density Lipoprotein (L DL) and High Density Lipoprotein (HDL). LDL is the bad cholesterol, which people fear. It is deposited as a plaque on the walls of the blood vessels, narrowing the radius, which in turn, combined with a high blood pressure, may lead to a thrombosis and even stroke. While the LDL creates a mess in the body, the HDL functions as a janitor, cleaning up and lowering the levels of LDL [15]. A study sustained by Hambrecht et.al [18] showed an increase in HDL levels in people who performed aerobic intervals. These findings agree with McArdle et.al [15], who also claim that physical exercise increases HDL and lowers LDL. The increased level of HDL, combined with decreased LDL levels and blood pressure, significantly decreases the risk of getting heart problems, which in turn should be a good pretence for all people, owning a heart, to perform physical exercise.

As already mentioned, the meeting room where the *heart and software* is placed will be holding many inactive grown up people. A normal grown up thing to say is something like: “Exercise yeah! I’m in tip top shape! I trained my entire youth every day so I reached an enormous level of fitness and does not need to exercise so much nowadays”. Correct statement? Certainly not. One of the major principles of all kinds of exercise is reversibility. The human body is a master of adaption, which means that if trained with heavy weights, the body adapts by getting bigger and stronger, and if you run a lot, your body responds by increasing your oxygen consumption and running capacity. But the word adapt reveals the fact of adaption to everything, which in turn means that if you do not overload any of the systems of the body, the body does not just stop adapting getting stronger or faster, but in facts starts to adapt to inactivity. Sitting by a desk reading papers and calculating numbers have very low physical requirements, and major physical setbacks will in very short time be a fact. Reversibility in physical fitness level is very well demonstrated in numerous studies, for instance in the Dallas bedrest study [19, 20]. This study showed that 30 days of bed rest decreased physical fitness level more than three decades (30 years) of aging. The Dallas bedrest study should refer to the importance of not using former exercise as an excuse for inactivity.

"I'm starting to get old and stiff son. Training can't do much with age you see, so I think this old body of mine is better off taking a nap, leaving the exercise to you kids." This is another famous middle aged phrase. Also this statement is untrue, and probably the worst excuse not to exercise. According to McArdle *et.al* [15], age is not a limiting factor for exercising. The fact that aging in some way induces reduction in fitness level, due to different mechanical and chemical factors, is inevitable, but the effect of training is still the same for a 20 year old and a 80 year old [15]. The Dallas bedrest study also showed that 50 years old persons could reach their 20 year old fitness level by aerobic training, and that the main reason for older people loosing their fitness was due to inactivity. The Dallas bedrest study clearly demonstrates the enormous effect of reversibility, and when viewed together with inactivity, one sees that people not exercising are getting old extremely fast, and that this fast ageing of the body is due to as simple as not being active and not only the aging itself. This means that persons, blaming their old body for not exercising, are those who really should be doing exercise, preventing their body becoming even older.

By watching the *heart and art*, with the ECG wave, maybe some people, as mentioned, start to think of their own heart as a concrete thing which needs nursing and training, and hopefully start to do something to keep it for as long as possible.

# 4. Design and Implementation

## *4.1 Product design and Specifications*

There are three groups that chose the *veggidi* project. This made co-operation between the groups a crucial and challenging task, especially when it came to building the wall. The three groups had to agree upon a common physical set-up of the circuit boards, which put critical limitations to our decision process in settling for our final idea.

### 4.1.1 Method

The art was made by mounting circuit boards on wooden frames. Each board was 30x30cm and we were given a total number of 116 boards. In case of technical problems with the boards, only 96 were used, which left us with 20 spare cards. Further, there was produced 18 wooden frames by the janitor`s workshop at Gløshaugen, with only 16 of these used. Each of the frames was 90x60 cm, and contained the capacity of holding 6 boards. Screws for mounting where purchased from the janitor at the IT-building. Also, the janitor and some of the group members, provided with screwdrivers.

For each of the boards, one Ethernet and one power cable were used, which added up to a total number of 96 for each. The circuit boards were programmed using flash software. An ECG wave was used as a template in the window of the flash software program, and consecutive layers were generated in which a line traced this template bit by bit for each new layer, starting from the left corner and propagating to the right. In a real life ECG recording, the speed of the paper (or the horizontal speed on the ECG monitor) is constant, so when the QRS complex appears, the trace moves faster because of the big deflections. Our method with new layer over preceding layer did not reflect this accelerated speed in the vertical direction, because the cursor then propagated with a constant speed along the wave on the template. This problem was solved by speeding up the shifting of consecutive layers when the cursor reached the QRS complex, thus imitating the heart beat as one would see it on an ECG monitor and making the horizontal speed of the cursor approximately constant.

### *4.1.2 People involved*

The project was sustained by a group of six students, with equally distribution between the sexes. Each was from different faculties from Norwegian University of Technology and Science (NTNU), and ranging from 23-30 years of age. The students were from medicine, art, political science, computer science, biotechnology, and exercise physiology and sport science. The many backgrounds resulted in a broad specter of skills and different ways of thinking and solving problems, which contributed to a vide competence within the group.

Letizia Jaccheri was the contractor for the project. Together with two student assistants, Anne-Marie Haugen and Martin Almaas, and the architect Espen Gangvik as well, they contributed to the group by helping organizing the project, by suggesting strategies for acquisition of materials, and discussing theories and ideas that the group evolved. This, in turn, led to more concrete ideas within the group.

Three different groups worked separately on the *veggidi* project. Each group worked separately on the idea and the theoretical part, but the practical part was done as an integrated result between the groups. This included all the practical aspects of setting up the wall. Deciding and ordering the framing of the art, screwing the cards on the wall, and programming of the cards, were therefore done together by representatives from all three groups.

### *4.2 Implementation & Methods*

#### 4.2.1 Data collection:

It was necessary for our project to collect information on former artworks relevant to the project, as well as information on LED and EKG. Various books, scientific journals and web pages were used for this purpose. The background investigation was not very time consuming, as our group had the necessary competence within all the fields in question.

#### 4.2.2 Task distribution:

Given the short time span and large workloads of this project, extensive planning and task distribution was of great importance. Early in the process, we decided on a division of roles and a distribution of responsibility within our group. The distribution of roles and areas of responsibility were as follows: Team manager (Egil), secretary (Kjell), responsibility for the frames (Vegard and Christina, together with members of the other two groups). This responsibility included communication with the other groups and finding solutions, to provide the necessary equipment and to mount the wall.
Egil worked with one member from each of the other two groups on hardware/software

issues. Egil's responsibility was to manage the aspects of the wall related to networking and power supply. He also had to configure the computer which was used to control the wall. Chung-Eun and Elisabeth were mostly involved with the writing of reports and preparations for presentations.

It should be mentioned that all the members were involved with the various parts of the project, even though the roles and distribution of responsibility in general were normative for the task distribution.

### *4.3 Plan for Mounting*

In the process of mounting the wall, the three groups faced some obstacles along the way. Prior to the start of the village, the intention was that the wall would be set up using an aluminum frame. As such a frame was not available; we had to agree upon another solution for mounting the circuit boards on the wall. In the beginning, the groups also found it difficult to make an agreement with a workshop to have the frames made, considering the limited amount of time available. The janitor also expressed his worries about the weight of the installation and how to fix it on the wall in a secure manner.

The three groups agreed to fix the circuit boards on the wall by using smaller modules of wooden frames put side by side on the wall, and each circuit board would then be screwed onto these frames, making the frames and all the wires hidden behind the circuit boards, and the circuit boards themselves would appear visible for the people using the room. The janitor fixed the wooden frames on the wall; eight frames put side by side in two rows, adding up to a total of sixteen frames. Members of all three teams then co-operated in groups of two to fix each circuit board to the frames using screws. The boards were set up along the rows, and when some boards had been fixed in one row, the mounting could then be initiated on the row below. This way of organizing the work proved to be very efficient. Six boards fitted into each frame, adding up to a total of 96 circuit boards that were fixed to the wall, yielding the final dimension of 16 circuit boards along the rows and 6 circuit boards down the columns. As each board has a 5 x 5 matrix of LEDs, the number of LEDs along the rows added up to 80, and the number of LEDs along the columns added up to 30.

When fixing the circuit boards to the frames, each board was also connected to an

Ethernet cable and a power cable, and because the cables run beneath the frames, eventually appearing at the bottom, we had to be sure to mark each Ethernet cable by a unique number, so that we would know which cable were connected to a specific circuit board.

### *4.4 Testing*

As each pair of columns was completed downwards from left to right, the different segments of the wall was tested step by step for adequate responsiveness by applying electricity to the circuit. The boards which lit in a satisfactory manner were identified in this way, as well as the boards which did not light up or which behaved otherwise than expected. The boards that did not function satisfactory were fixed or replaced by spare boards, making it possible to eventually obtain a wall in which all the circuit boards were functioning well.

### *4.5 Results & Description of Product*

The outcome of the implementation was a finalized product, which resulted in a complete piece of art. The mounting was successful in the desired way with all the frames connecting to each other, so that it could be viewed as a whole, single object with circuit boards covering the entire surface. Further, all the connections with power and Ethernet cables were completed, and it became possible to light the LEDs and program them individually. The end result was a complete wall covered with circuit boards with the ability to create light in desired ways.

**Fig. 4.1.** The complete ECG wave after having travelled from left to right on the screen

.

Due to the limited amount of time, but in proportion to the plan, the presentation on the wall resulted in a prototype of the idea. The image switched between showing an ECG wave moving across the boards from left to right and a flat line moving across. The picture above shows the complete ECG wave before going over to flattening out (Fig. 4.1). Further, on the picture below, the ECG wave flattens out, and demonstrates the desired future effect of someone stepping into the electromagnetic field on the floor (Fig. 4.2).

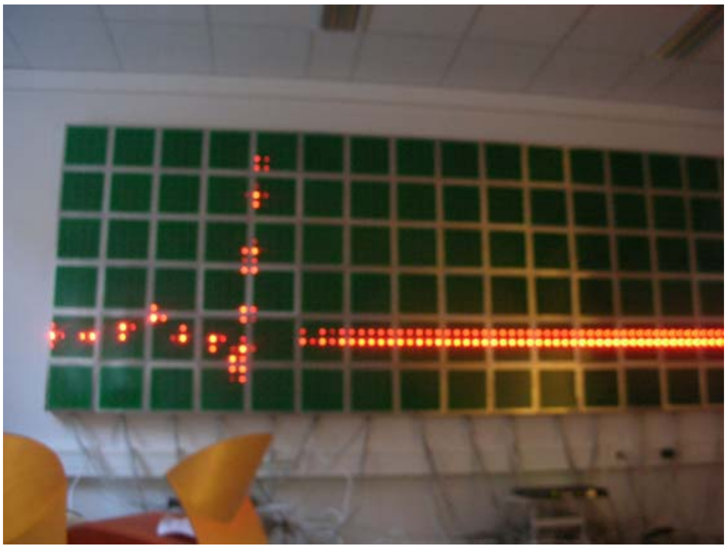

**Fig. 4.2.** The ECG wave turned into a flat line for every second cycle.

# 5. Discussion

In this section evaluation of the product and some comments during the project are stated.

### *5.1 Limitations*

The three weeks time limit for the project put limitations to the complexity of possible ideas and solutions. The mounting of the wall was completed at a late stage in the project, resulting in less time for the programming, testing and adjusting the product. There were two other groups that had also chosen the same project, which were to co-operate with, restricting us to agree upon a common physical frame.

### *5.2 Evaluation of our product*

The mounting of the wall went very well without any significant problems. It was a very good practice in co-operation between team members and between groups, and it appeared to be the most productive day in the whole process when it came to realizing the project. A little roughness in the frames of the circuit boards introduced some asymmetry in the lining of the boards on the wall, but we were very pleased with the overall result and the appearance of the wall. An ECG wave was successfully displayed on the wall, and it was also recognized as such a wave by the audience in our presentation of the product.

In our presentation, we gave some examples of how the ECG wave could be interpreted by people experiencing it in the room. Our interpretations were rooted in our different backgrounds, and our thought was that every person will interpret the product in their own way and perhaps bring in their own professional background in their reflections.

### *5.3 What could have been done differently?*

There were some other ideas that could have been applied to this project.

#### 5.3.1. Ideas that were abandoned

When it comes to choice of idea, there were also other suggestions that we considered during the process. These ideas were abandoned due to technical obstacles in relation to our time schedule, but are not rejected as possible ideas and can be realized in the future.

As the room is often used as a conference room, one of our suggestions was to have a sound-sensor monitoring the sound level during a meeting. The sound-sensor would be used for sensing the speaker's sound level and whether he/she speaks loud enough for others to hear the presentation. Another way of interacting with the wall would be to use a sensor that senses the movement in the electromagnetic field located on the floor in the middle of the room. If someone happens to step into this radiation zone, the wall displays a warning. The idea was left in favor of our chosen idea and because of the limitations we faced when exploring the possibilities for realizing the sensors needed. Our chosen idea can stand alone without the sensors in a better way.

One of our other ideas was to install the circuit boards in the ceiling and also to be able to move the boards in some way. However, the ceiling may not be able to tolerate the weight of the installation. Besides, two other groups had chosen the same project, so we had to agree upon the same frame for the circuit boards. Another idea was to make the wall a "living being" in the sense of visualizing the state of sleeping, being lonely or sad, etc. However, we found that the resolution of the light pixels limited our way of expressing these feelings. Finally, we also had an idea in which some waves would be displayed on the screen with a surfer cruising on these waves, pointing to the action of surfing on the net. However, we found it hard to put a multidisciplinary dimension into this idea.

### 5.3.2 Programming

Our method with consecutive layers, which prolonged the ECG wave for each layer, was perhaps not the optimal solution for our purpose. After the animation had been made, we reflected upon an alternative method which perhaps would be simpler and faster to implement, and which would meet the criteria for constant horizontal speed in a more elegant and exact way. If we could have the whole template as a basic layer, then a second layer could cover the whole template in the beginning, and then each new layer, being applied at constant intervals, could uncover the underlying ECG wave bit by bit from left to right, thus giving the same propagating ECG wave on the screen and now moving in a truly constant horizontal speed.

### *5.4 How could our product be developed further in the future?*

The interaction part of our original idea was not implemented in this project. Although we had to put limitations on our idea in this way, we would like the idea as a whole to hopefully be realized by others after our product is delivered. We have therefore attempted to implement our solution in such a way that others can continue from where we stopped and perhaps could manage to realize the interactive part of the idea.

## 6. Conclusion

The main purpose of this project was to reuse the given software/hardware technology and create a new piece of art. The idea the group came up with was to have an ECG wave propagating along the wall, and this idea satisfied the criteria we had agreed upon. We also managed to realize the mounting of the wall in cooperation with the two other groups working for the same contractor. We were able to display our idea on the wall in a satisfactory way, except for the interactive part of the idea, which we suggest could be a possible alternative for future development of the wall.

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