Lars Føleide

Digitally Augmented Table Tennis User Experience

Master's thesis in Informatics
Supervisor: George Adrian Stoica
Co-supervisor: Terje Røsand
December 2021

Master's thesis

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Abstract

With the emergence of the internet a new world of possibilities opened up. Decades later, as the term Internet of Things (IoT) gained popularity, it has become possible to digitally augment the table tennis user experience. This study, built on a user centered design, has explored ways in which tennis table can be digitally augmented while preserving anonymity and privacy. It has thereafter explored how digital augmentation can improve the table tennis user experience and increase availability awareness.

The user centered design approach has made the study exploratory, as there is an iterative aspect in the methodology in which findings during the study determine the direction going forward. One example is how a preference for a queue system was expressed when asked about booking during the initial user testing study using eye-tracking. This became the basis for testing a digital queue system in the second user testing study, with the application of eye-tracking.

The findings from this research show that a vibration sensor allows for table tennis to be digitally augmented, while preserving anonymity and privacy. An improvement to the use of cameras and projectors for digital augmentation, still providing useful information like table tennis availability which improve the user experience. The study explored initial challenges in building hardware for the necessary collection and processing of vibration data, before shifting focus to the user experience. The research has employed a wide variety of methods for data collection to ensure emphasis on the user centered design approach, so that the service was built in accordance with user requirements. In the initial phase user requirements had to be identified, and improvements to the service was done after testing for user requirements. This study has shown that digital augmentation improves the table tennis user experience through increased availability awareness.

Keywords: digital augmentation, user experience, table tennis, internet of things, user centered design approach, eye-tracking, user testing

Sammendrag

Med internetts utvikling åpnet det seg opp en ny verden av muligheter, og flere tiår senere, i tråd med økt popularitet rundt begrepet tingenes internett, har det blitt mulig med digital utvidelse av bordtennis brukeropplevelsen. Denne studien med utgangspunkt i brukersentrert design, har utforsket hvordan bordtennis kan digitalt uthevet samtidig som anonymitet og personvern blir ivaretatt. Det har blitt studert hvordan bordtennis brukeropplevelsen kan bli forbedret med digital utvidelse og hvordan digital utvidelse av bordtennis kan øke tilgjengelighetsforståelsen.

Brukersentrert design tilnærmingen har gjort studien utforskende, ettersom der er et iterativt element i metoden hvor funn underveis i studien bestemmer veien videre. Et eksempel er hvordan en preferanse for et køsystem ble gitt uttrykk for etter spørsmål om et bookingsystem, under innledende brukertesting studie ved bruk av blikksporing. Som gjorde at et digitalt køsystem ble testet i en ny runde med brukertesting ved bruk av blikksporing.

Funnene fra studien viser at en vibrasjonssensor gjør det mulig for et bordtennisbord å bli digitalt utvidet, samtidig som anonymitet og personvern blir ivaretatt. En forbedring til bruk av kamera og prosjektør for digital utvidelse, hvor nyttig informasjon som bordtennis tilgjengelighet gjør brukeropplevelsen bedre. Studien så innledningsvis på utfordringer knyttet til utviklingen av en sensor for nødvendig innhenting og prosessering av vibrasjonsdata, før fokuset gikk videre til brukeropplevelsen. Mange forskningsmetoder er tatt i bruk under datainnsamlingen for å sikre i henhold til brukersentrert design tilnærmingen at tjenesten utvikles i henhold til brukerkrav. Brukerkrav ble innledningsvis identifisert, og utbedringer til tjenesten ble utført etter å ha testet om brukerkravene er løst på et tilfredsstillende vis.

Nøkkelord: digital utvidelse, brukeropplevelse, bordtennis, tingenes internett, brukersentrert design, blikksporing, brukertesting

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1. INTRODUCTION

In the last 100 years, humanity has largely been moving towards a more sedentary lifestyle, often sitting or lying down while engaged in activities like socializing, watching television, playing video games, reading or using a mobile phone for much of the day. Students and a growing portion of the workforce are required to spend considerable hours on a computer throughout the day, giving rise to an increased need for activity breaks. At universities and office buildings, you might find table games (such as table tennis), aiming for allowing students and employees activity breaks from their work. The positioning of these artifacts may cause difficulties in checking whether the table is already in use, or others are about to initiate a game. This, in turn, makes it challenging to plan a short game between reading sessions.

Through augmentation, it is possible to introduce a higher level of awareness with regards to the table game (e.g. table tennis), in order to satisfy this need for awareness and make the experience more interesting. Augmentation might promote more active usage and subsequently motivate for more active breaks. An example of augmentation is shown in the figure below. Information is projected on top of the tennis table, and a camera detect movements. This allows the user to choose different training programs, using a dashboard on the table and activating various options with a touch interface. In the illustration below, the user completes the task by bouncing the ball within both circles on both sides. If successful, the circles get filled with a green color on one side and blue color on the other side.

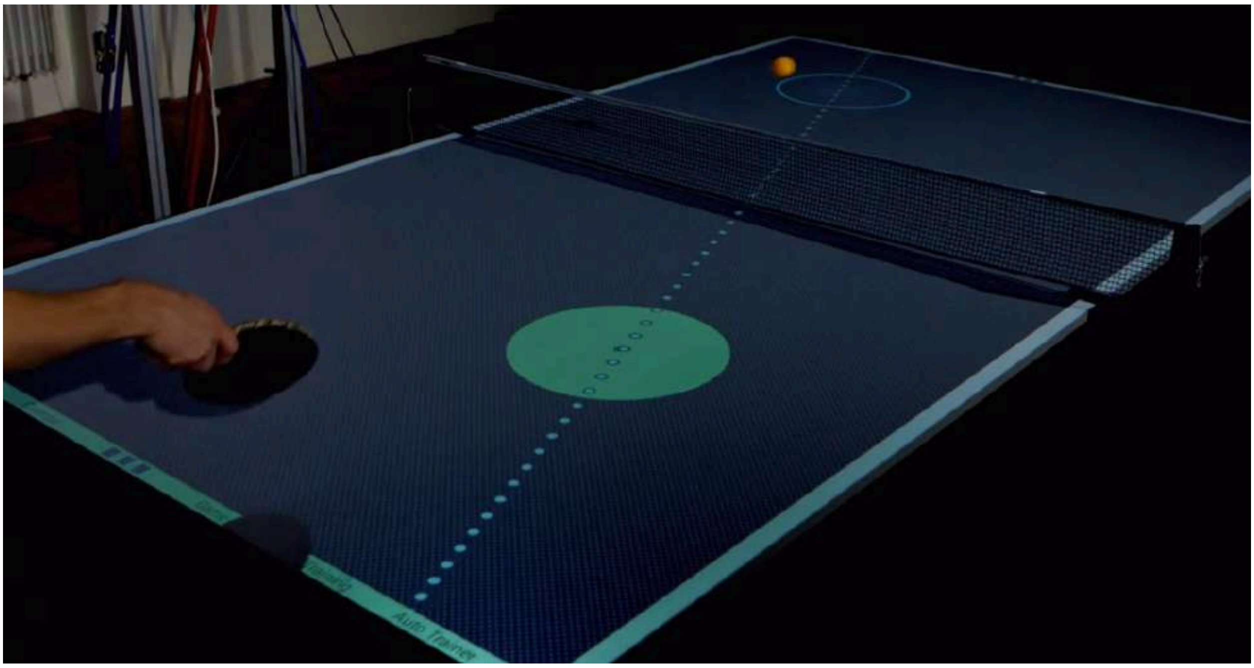


Figure 1.1: Table Tennis Augmentation using projector and camera (Mayer 2016)

While augmentation typically refer to a visual information overlayer, digital augmentation can also refer to the availability of information from physical spaces through a digital medium. Digitally augmented artifacts extend information, such as vibration data, so it becomes possible to determine usage without being physically present.

This thesis has two investigate aims. First, how we can improve the game experience in the above-described context using hardware and software augmentation of table tennis. Second, how technology can make services like table tennis more accessible through digitally augmenting the table tennis user experience. Depending on the user profile, the tennis table augmentation should be conducted to be unobtrusive, considerate of privacy and anonymity preferences.

1.1. Research questions

Research Question #1:

In what ways can table tennis be digitally augmented while preserving anonymity and privacy?

Research Question #2:

How can digital augmentation improve the table tennis user experience?

Research Question #3:

How can digitally augmented table tennis increase availability awareness?

2. THEORY

In this chapter, relevant theoretical literature for this study is presented. It includes literature about preserving anonymity and privacy, Internet of Things (IoT), the user centered design approach, eye tracking, and digital augmentation. With the ongoing Internet of Things revolution, it has become possible to blend hardware and software in new and innovative ways; resulting in web services more complex than before, making development more demanding. Designers therefore need to consider a broad aspect of users to deliver systems that meet requirements. While it is becoming more commonplace to have information from the outside world accessible through your phone, the process of designing these services is still challenging and require a set of carefully selected methodologies. The user centered design approach and eye tracking combined ensures that the user requirements are at the center of the design process. The combination helps to verify that users actually understand the flow in the user experience. Users are introduced to many concepts, from the gathering of data through Internet of Things technology, to digital augmentation of this data, so including users in every step of the current study has been important.

2.1. Preserving Anonymity and Privacy

Anonymity relates to a person being non-identifiable, unreachable or untraceable (Wallace 1999; Nissenbaum 1999). Privacy is about the right of people to determine how, where, when, and who can use their data (Yamin et al. 2019). Preserving anonymity therefore relates to not being able to identify the person of which data is collected, and not being able to use collected data to trace the person. Preserving privacy relates to the prevention of personal data being misused. Personal data is identity, contact details, location, financial condition, health, social status, education level, etc. An effective method for preserving privacy is to collect data that cannot be used to identify individuals. Vibration sensors are anonymity and privacy preserving choice of data collection, as they entail no visible cameras and do not identify who is playing. This is an improvement to the use of cameras and projectors for digital augmentation, while still providing useful information like table tennis availability. The user experience can be improved through increased available awareness using vibration sensors, while still preserving anonymity and privacy.

2.2. The Internet of Things (IoT)

The Internet of Things (hereafter abbreviated as ‘IoT’) is a term that initially was coined in the late 1990s to promote RFID technology, but it is only in the last decade that the term has gained mainstream acknowledgment. Internet of Things is defined as “Sensors and actuators embedded in physical objects linked through wired and wireless networks”, a widely adopted definition by McKinsey. In other words, a network of physical objects embedded with sensors and software with the purpose of connecting and exchanging data with other systems over the internet.

When the telephone, radio and TV were introduced, technology adoption were fast. One of the fastest adopted technology has been the smartphone, which has helped give a boost to the adoption of IoT devices. Many factors have helped drive the IoT adoption, like falling prices, system on chip devices like Arduino getting WiFi access, and the ability to integrate mobile data at affordable prices. The emergence of internet of Things has made products like “smart home” possible, allowing lighting fixtures, thermostats, home security systems, cameras, etc. to be connected to a central system. Which allows for aspects of the system to be controlled with devices associated with the ecosystem, such as smartphones and smart speakers. In addition to Home Automation, we find that IoT technology is used in fitness trackers, Industrial asset monitoring and Smart energy meters. The connection of physical things to the internet makes it possible to access remote sensor data and to control the physical world from a distance (Kopetz 2011), enabling the use of IoT for augmentation. Sensor data can be augmented. A physical object can come to life with IoT technology, in that information about the object can become accessible remotely without the need to be in physical proximity.

2.3. User Centered Design

The idea of needing to put users in the center started to emerge in the late 1960s. This is the point at which we began to realize the potential for computer-based technologies, as shown by the following quote: ''the need for the future is not so much computer oriented people as for people oriented computers'' (Nickerson 1969). The time period gave rise to the User Centered Design (Norman 1986) and Human Centered Design (Cooley 1989), both concerned with the human-computer interaction with slight variations. User Centered Design focused on the user's needs, the analysis of doing an activity, requirements analysis, early testing and evaluation, and the process of iterative design (Ritter et al. 2014). Human Centered Design expanded its focus to considering how human capabilities are affected by system, looking beyond direct interaction with the interface itself (ibid.).

User Centered Design is at the foundation of this study, having initially set out to understand and specify the user context. Semi-structured interviews were conducted to understand user preferences and to specify user requirements, in accordance with step two in the User Centered Design approach, illustrated in the figure below.

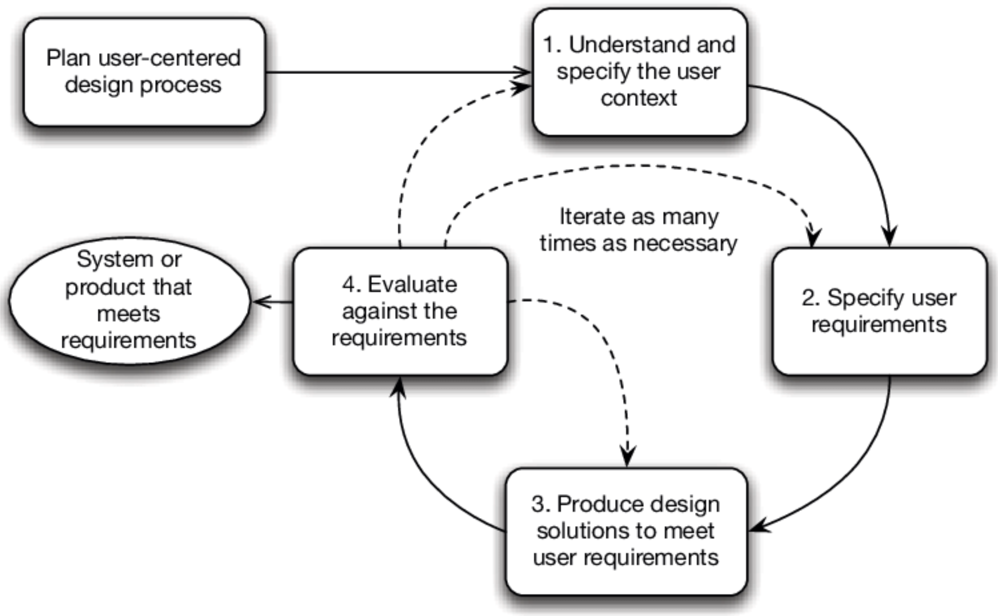


Figure 2.3.1: User Centered Design approach

The four general phases of the User Centered Design process are as follows:

1. Specify the context of use
    - Identify the people who will use the product, what they will use it for, and under what conditions they will use it.
2. Specify requirements
    - Identify any business requirements or user goals that must be met for the product to be successful.
3. Create design solutions
    - This part of the process may be done in stages, building from a rough concept to a complete design.
4. Evaluate designs
    - Evaluation - ideally through usability testing with actual users - is as integral as quality testing is to good software development.

The process is complete when product meets requirements, otherwise iterate as many times as necessary. The international standard 13407 (User Centered Design 2020) is the basis for many User Centered Design methodologies. Its design is based upon an explicit understanding of users, tasks, and environments. The user centered evaluation addresses the whole user experience.

2.4. Eye tracking

Usability testing has traditionally been done in controlled laboratory settings (Sharp et al. 2019). The approach emphasizes the usability of products and services, commonly used to evaluate desktop applications, websites, etc. Eye tracking is a method for measuring the point of gaze, a device that detect eye positions and eye movements as illustrated below (Toftøy-Andersen and Wold 2011). As most of the information we process comes through our eyes, Eye tracking is an important tool for developing a better understanding of how we process information. Eye trackers are used for research in psychology, marketing, as an input device and in product design. We make 3 to 5 eye movements per second. These movements are crucial for helping us deal with the vast amounts of information that we encounter in our daily lives (Holmqvist & Andersson 2017).

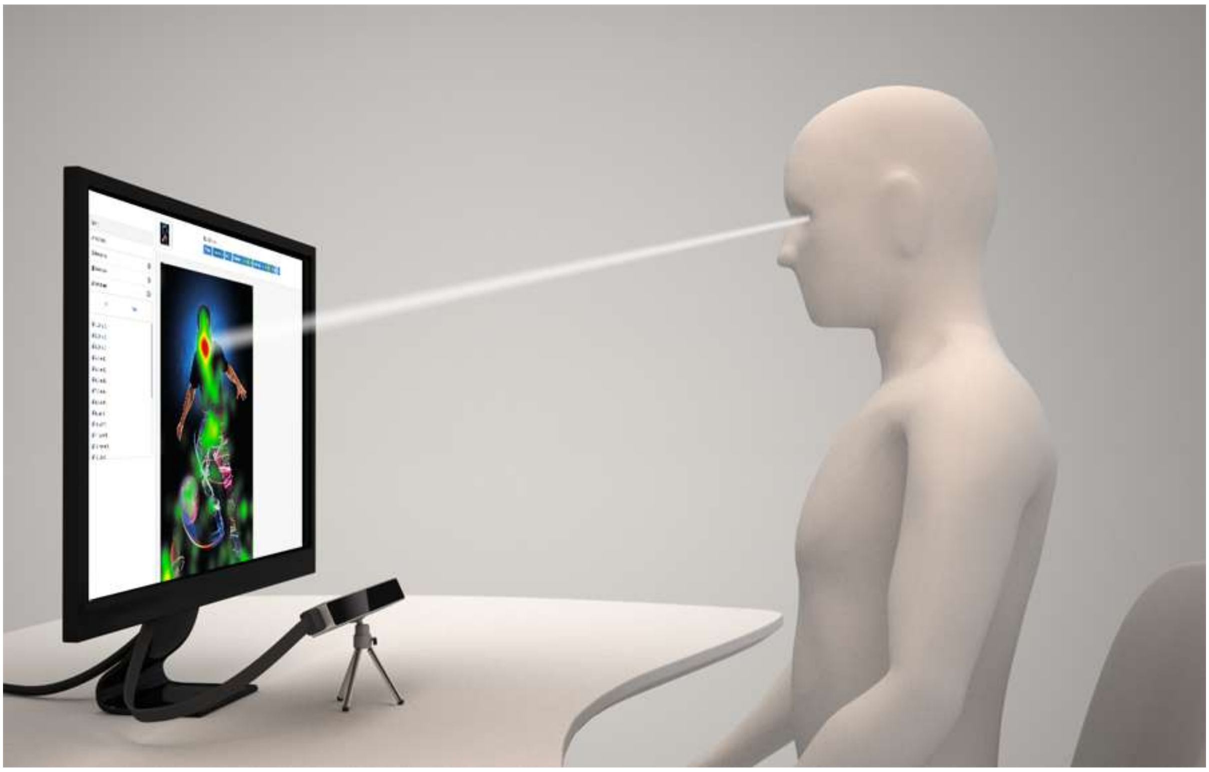


Figure 2.4.1: Eye Tracker for identifying gaze (Photo credits: © The EyeTribe)

The earliest eye trackers were built in the late 1800s. Mostly mechanical and not very comfortable for the participants. Before the 1980s, most eye-movement research were required to build their own eye tracking equipment before being able to use them to do research. The Yarbus Eye Tracker from 1960s is shown below.

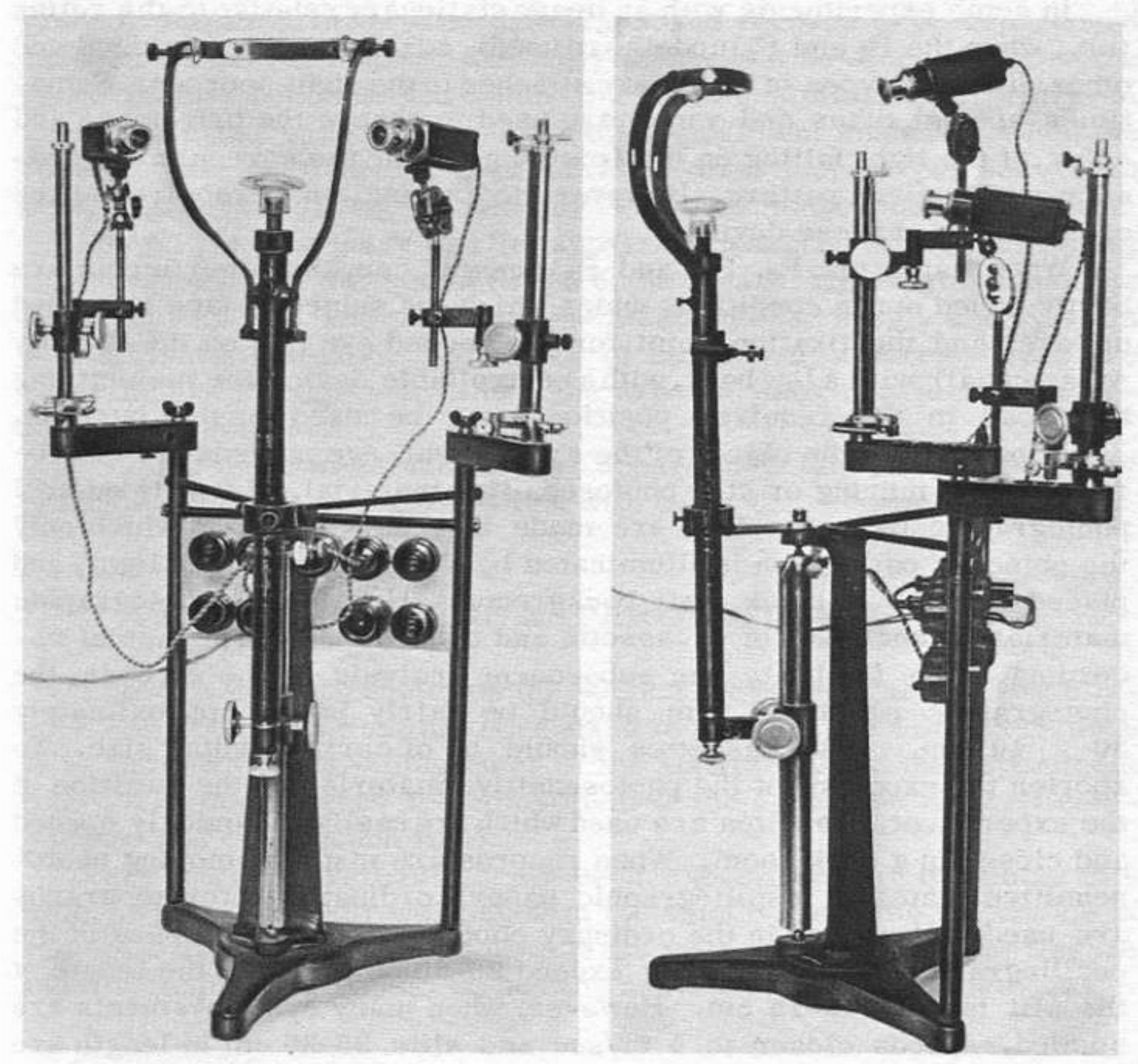


Figure 2.4.2: Yarbus Eye Tracker from 1960s
(Yarbus 1967 as referenced in Eye tracking 2021)

Eye tracking is today mostly done with infrared cameras. Eye Tracker using infrared cameras developed by Tobii is shown below. Subjects undergo a short calibration phase before tracking eye movements. Modern software is able to overlay areas that get attention in the user interface, and it is also common to use a regular web camera to also record the participant and also voice recording (Holmqvist & Andersson 2017).

Figure 2.4.3: Tobii Eye Tracker using infrared cameras (Photo credits: © Tobii)

The Tobii Eye Tracker use infrared cameras to track eye movements. At the user experience lab (UX Lab) on NTNU campus it is mounted at the lower part of the screen as shown in the figure below, allowing for Eye tracking session at the UX Lab. UX Lab is set up with Tobii Pro X3-120 and the software is Tobii Pro Lab version 1.142.27188 (x64) updated May 27th 2020.

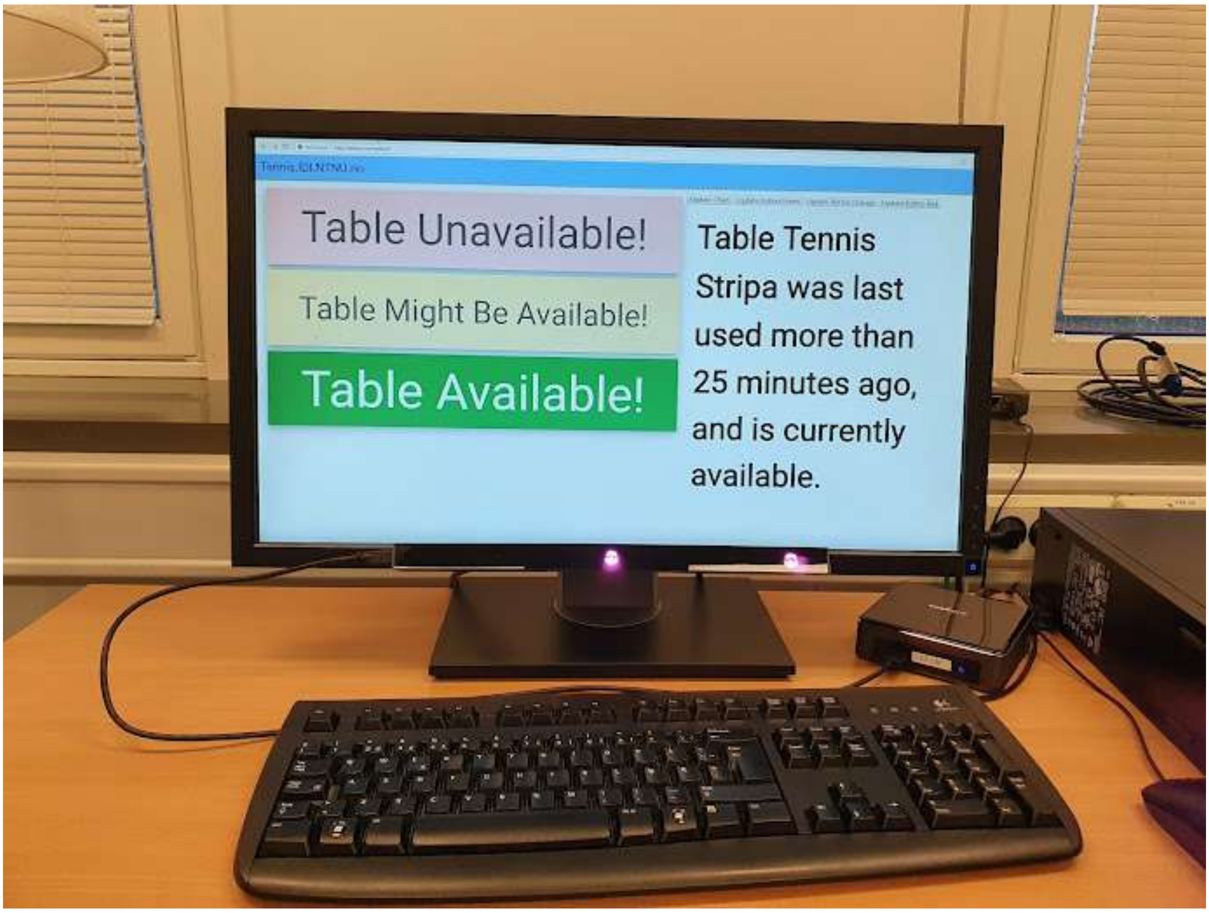


Figure 2.4.4: Tobii Eye Tracker in use at UX Lab, NTNU campus

2.5. Digital augmentation

Most of our perception of reality comes through our visual system, making the idea of a virtual reality intriguing. After decades of technology development virtual reality have become very immersive, with VR headsets that feature high resolution displays. As illustrated in the figure below, extended reality includes augmented reality which adds a layer of information to our perception of reality. For instance, glasses that make visible digital information on one of the eyeframes. Recently, mixed reality devices have become available that give a more immersive experience and the ability to interact with our virtual surroundings using hand gestures. Virtual reality devices are now also available with battery packs, which give freedom to move around while immersed in a virtual reality.

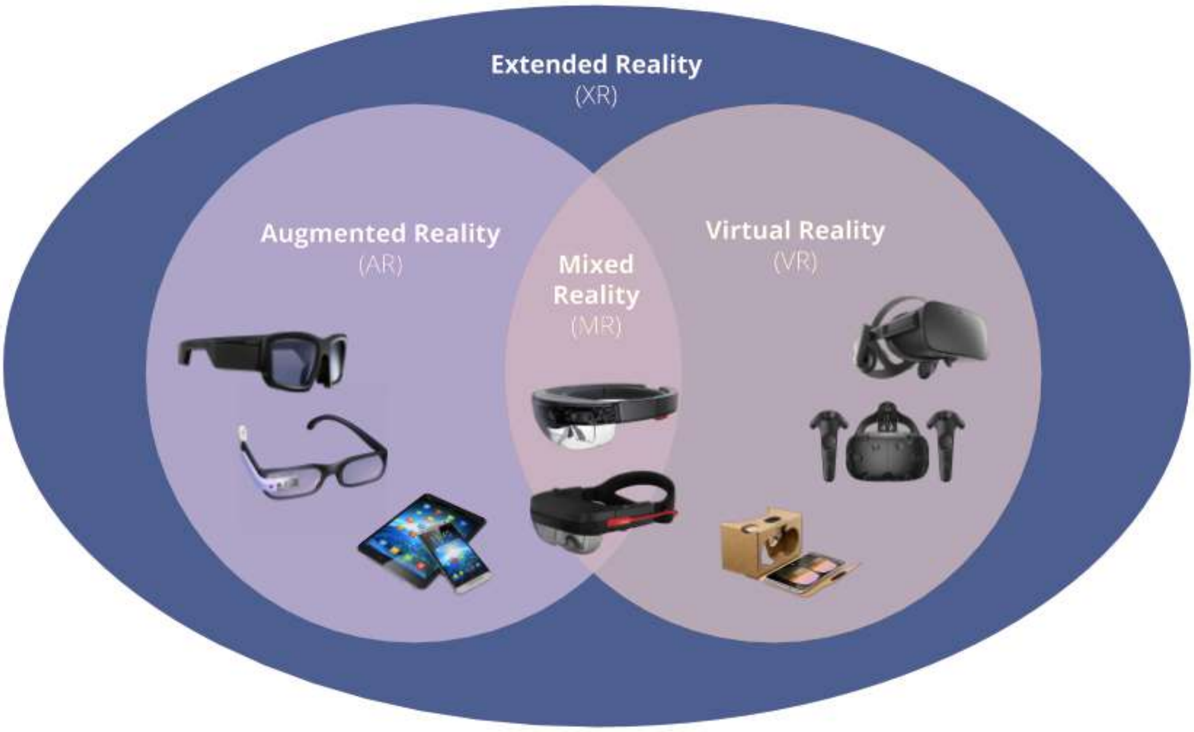


Figure 2.5.1: Extended Reality include both Augmented Reality and Virtual Reality (Adopted from: Thoughtworks 2020)

In the figure below (2.5.2), the extended reality spectrum can be described as having the real world on the left side, a real reality in which the user is fully aware of surroundings. As we move right on this spectrum, we find assisted reality as shown in the figure below, followed by augmented reality, and to the far right is virtual reality. The latter is computer-generated and user is fully immersed.

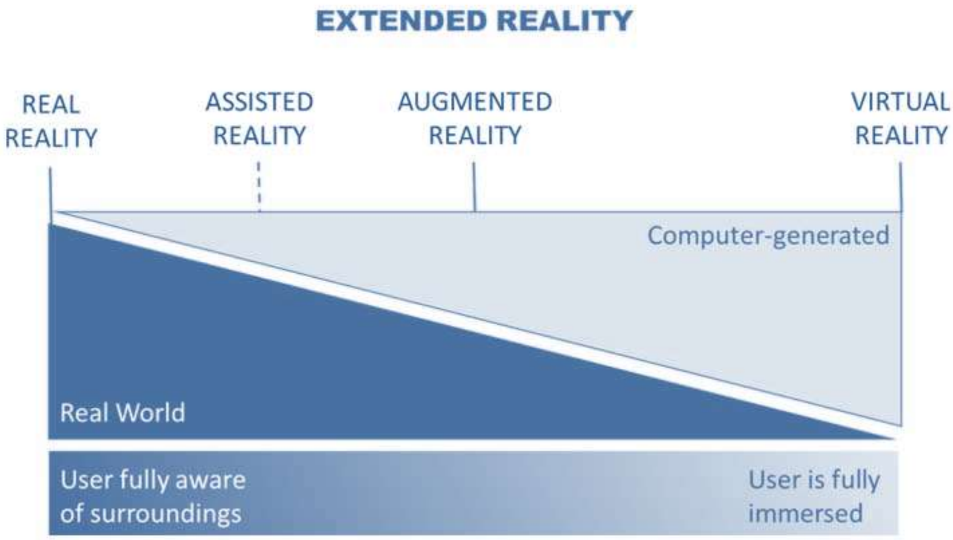


Figure 2.5.2: Extended Reality from Real Reality, Assisted Reality, Augmented Reality to Virtual Reality (Adopted from: Accenture 2020)

Augmentation is the act of enhancing or making something increase. Digital augmentation entails technology used to enhance our awareness of surroundings, for instance the way in which Google Maps tells you what street you are on through its Street View functionality. Digital augmentation refers to enhancing virtual presence with the use of digital content, like aiding workers in a manufacturing unit to go beyond what they would normally be able to do without the tool of digital technology. Physical artefacts can be extended with digital features, for instance bringing a table to life, so that it can tell the world that it is being used. With the application of “just enough” augmentation, both anonymity and privacy can be preserved. For instance, making assisted reality possible without intruding on the desire of people to preserve their anonymity and privacy.

MIT researchers at Tangible Media Group describe an implementation of PingPongPlus (Ishii et al. 1999), a “reactive ping-pong table”, featuring a novel sound-based ball tracking technology. With the addition of dynamic graphics and sound, the game is augmented and transformed, determined by the position of impact, rhythm, and the style of play. A video projector is used to display graphics and 8 microphones underneath the table is used to track movements of the Ping Pong ball as shown in the figure below.

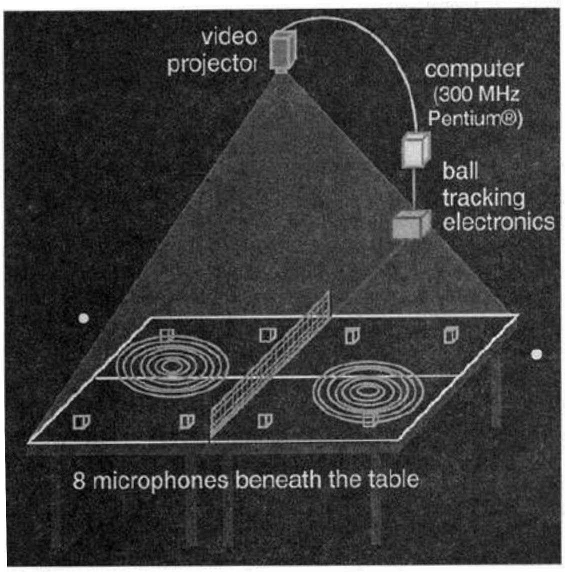


Figure 2.5.3: PingPongPlus system architecture (Ishii et al. 1999)

Augmentation is also used in Augmented Reality (AR), an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated perceptual information. In the article “AR Table Tennis: A Video-Based Augmented Reality Sports Game” (Park et al. 2006), gesture-based augmented reality games are described. Using QR codes on the racket and wall to better recognize gestures and correctly position an augmented tennis table as shown in figure below.

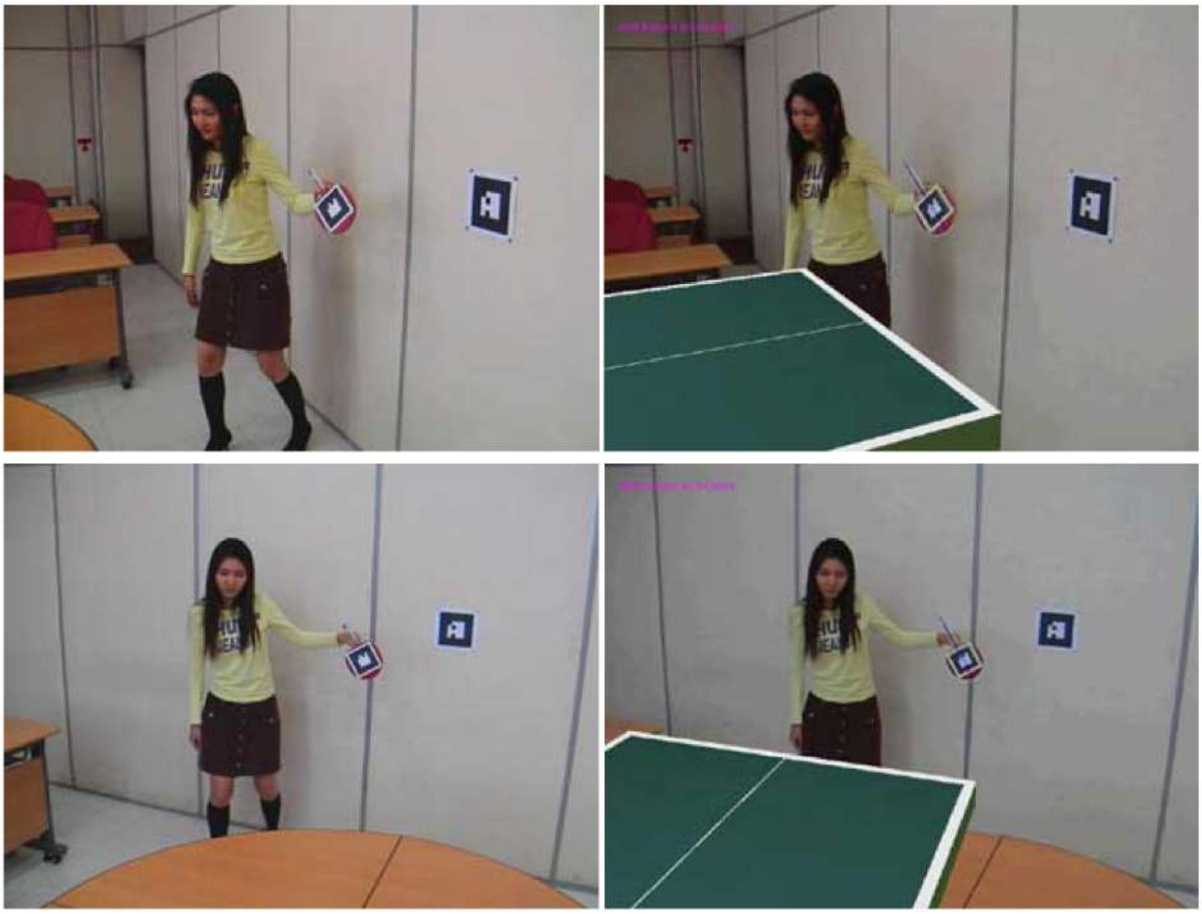


Figure 2.5.4: Game play with augmentation using QR codes (Park et al. 2006)

Augmentation in a digital form can also be used for three people at three different geographical locations to play table tennis together, as described in the paper “A Physical Three-Way Interactive Game Based on Table Tennis” (Mueller & Gibbs 2007). Table Tennis for Three requires three tennis tables that have the opposite side flipped, painted white and with a projector aimed at the white area. The system uses an acoustic-based detection system to determine the impact of the ball, combining gameplay with a videoconferencing component to support social interactions between geographically distant participants. There are 8 transparent boxes that all three participants see, which break upon the third impact. Every participant take part in the destruction of these boxes, but only the player who break it on the third impact get points, so everyone must be attentive to what other players are doing as illustrated in figures below.

Figure 2.5.5: Augmented Three Player Table Tennis (Mueller & Gibbs 2007)

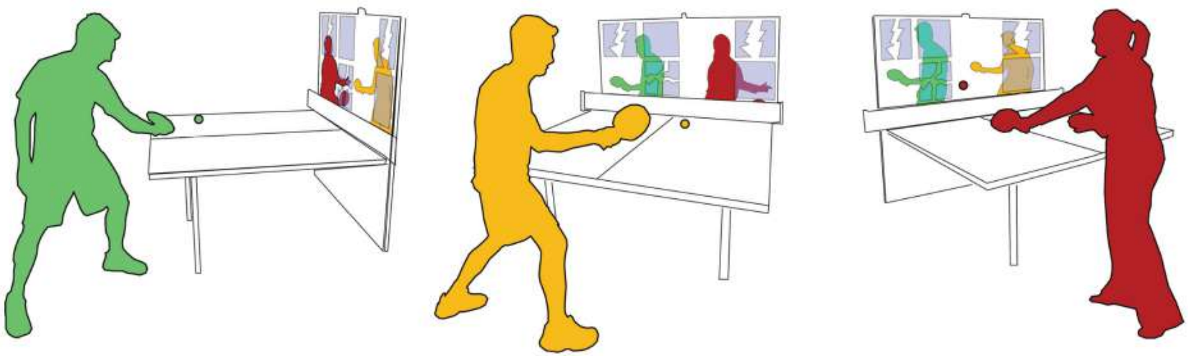


Figure 2.5.6: Blocks and hits are shared among the three players (Mueller & Gibbs 2007)

The PingPongPlus project by MIT Tangible Media Group from the 90s, which could track and visualize ball position, was later reinvented by MIT researchers at Tangible Media Group as PingPong++. A community platform, featuring a kiosk next to the augmented tennis table as shown in a figure below (Xiao et al. 2011). There are piezo sensors mounted under the table to detect positions of ping pong balls. These are connected to an Arduino, a processing unit and a projector as illustrated below. An example of augmentation is having fish swim around. When a ping pong ball hit the table, water ripples are created that scare away the fish (shown below).

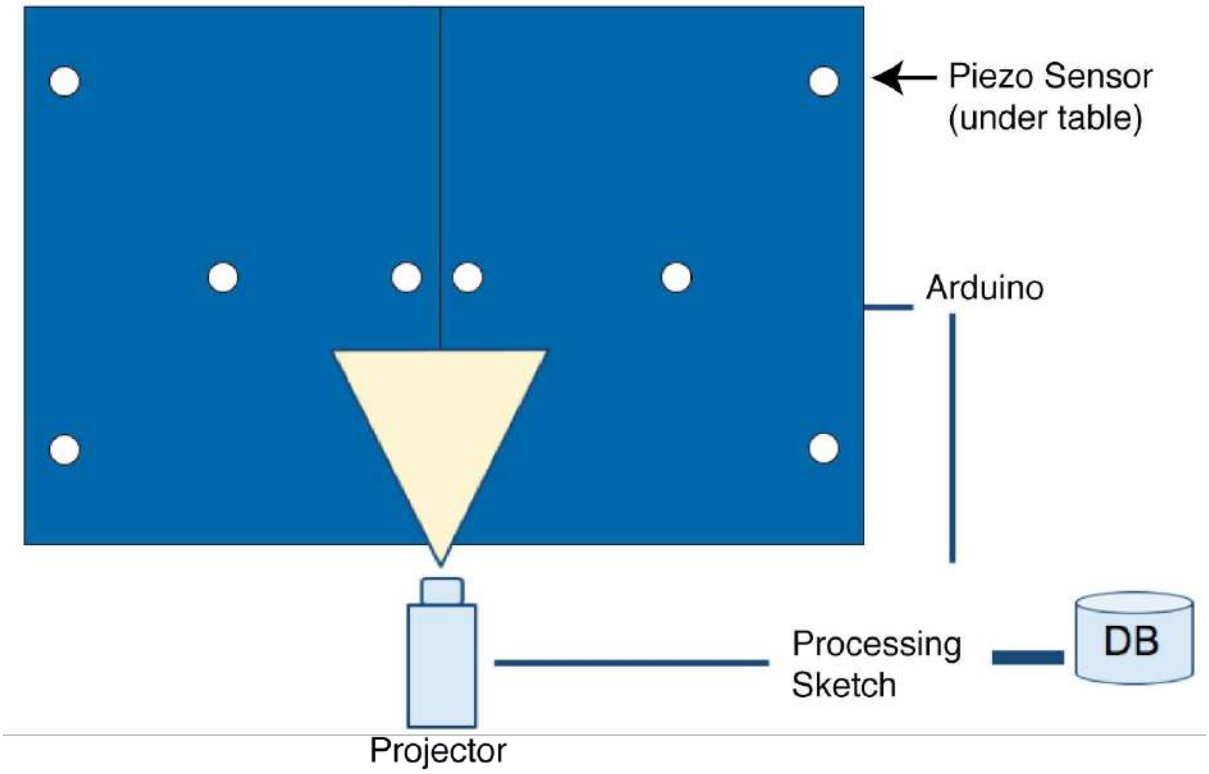


Figure 2.5.7: Hardware configuration of PingPong++ (Xiao et al. 2011)

Figure 2.5.8: Instant configuration kiosk for PingPong++ (Xiao et al. 2011)

Figure 2.5.9: A PingPong++ game. Ping pongs scare away the fish (Xiao et al. 2011)

In more recent years, Thomas Mayer took table tennis augmentation to the next level in his bachelor thesis using a projector and Code Laboratories Playstation Eye USB camera for tracking table tennis ball movements (Mayer 2016). The camera is suitable for capturing the table tennis ball in that it can be operated at 175 frames per second. The setup in shown in the figure below.

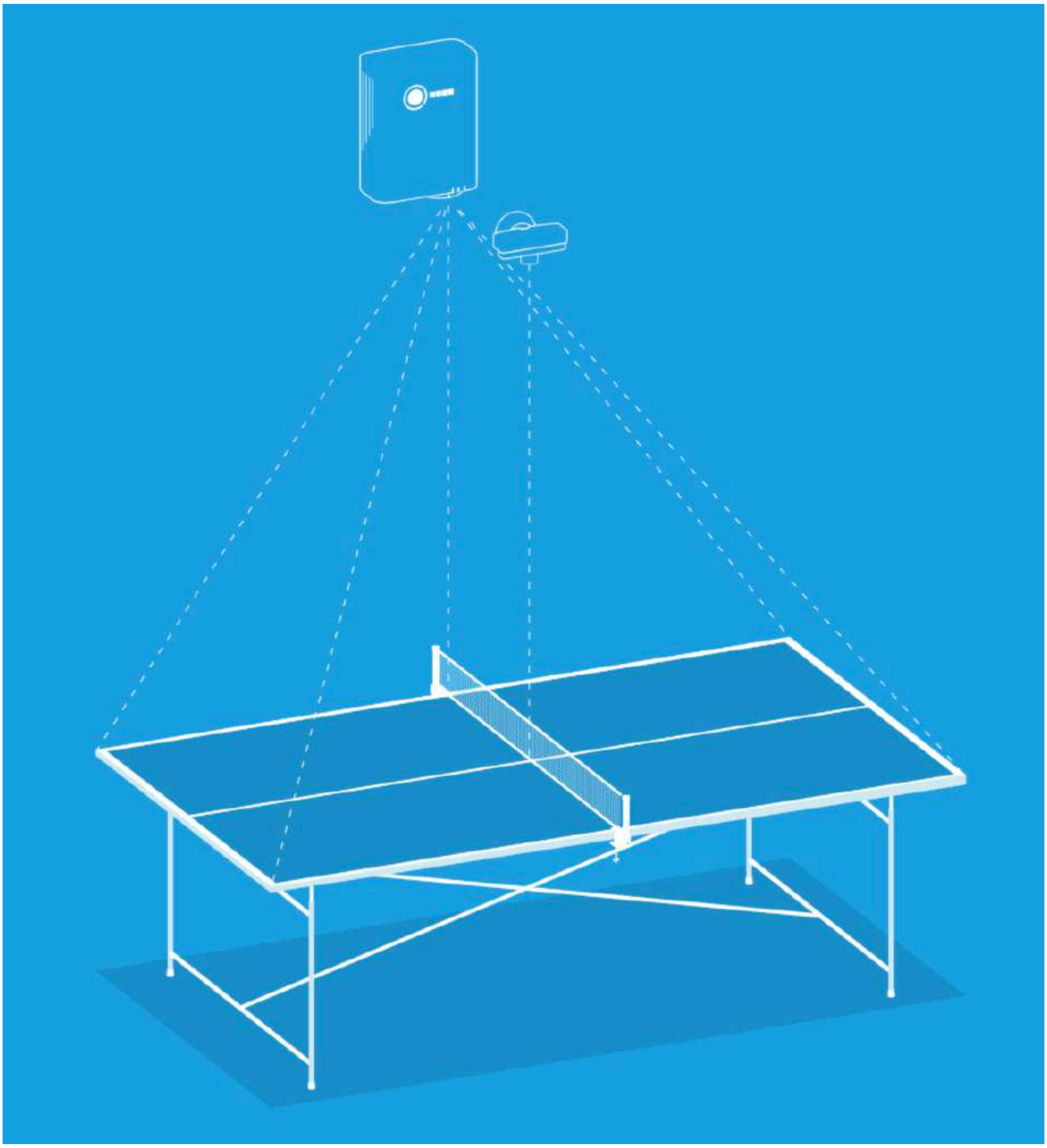


Figure 2.5.10: Table Tennis Augmentation using projector and camera (Mayer 2016)

Mayer built an extensive user interface that can be operated directly on the tennis table. An NFC-enabled racket allows for the player to log in, activating the dashboard, seeing recent matches, total score, current state of various skill sets in addition to target states, as shown in the figure below. The interface also features a trainer, with the ability to practice in order to obtain specific goals.

With the high camera frame rate, statistics can be collected about speed, sidespin, reaction time, precision, topspin, etc. and showing both current state and target state. The drawback of using a camera for tracking the ball as opposed to piezo contacts underneath the table, is that interference is caused when moving the racket above the table, which is a common occurrence. Especially for beginners.

Figure 2.5.11: Full projector view of dashboard (Mayer 2016)

3. METHODOLOGY

In this chapter, all methodological approaches for answering the research questions are outlined. With User Centered Design at the foundation of this study, it is natural to map research activities centered on the User Centered Design approach. *First step* in this approach is understanding and specifying the context of use. Observations were conducted to develop a better contextual understanding. While table tennis is a popular leisure activity throughout the semester, it is when students stop having lectures towards the end of the semester that the tennis table is in nearly constant use. Both for reasons of procrastination and the need to take breaks when spending all day studying for exams. It is not common for students to be in immediate proximity of a tennis table, since that would be very noisy, students therefore need to go for a walk to check if the tennis table is accessible or not. Constantly finding the table occupied makes many students tired of returning to their workstation emptyhanded, and eventually give up on the idea of finding the tennis table accessible. *Second step* is to specify user requirements from students who will use the service and identify user goals that must be met for the service to be successful. This was done through interviews, workshops and more observations. *Third step* is producing design solutions to meet user requirements, a process that may be done in stages, building from a rough concept to a complete design. A step that was done through prototyping. *Fourth step* is to evaluate the design, which was done through user testing. More specifically eye-tracking usability testing and interviews.

3.1. Timeline

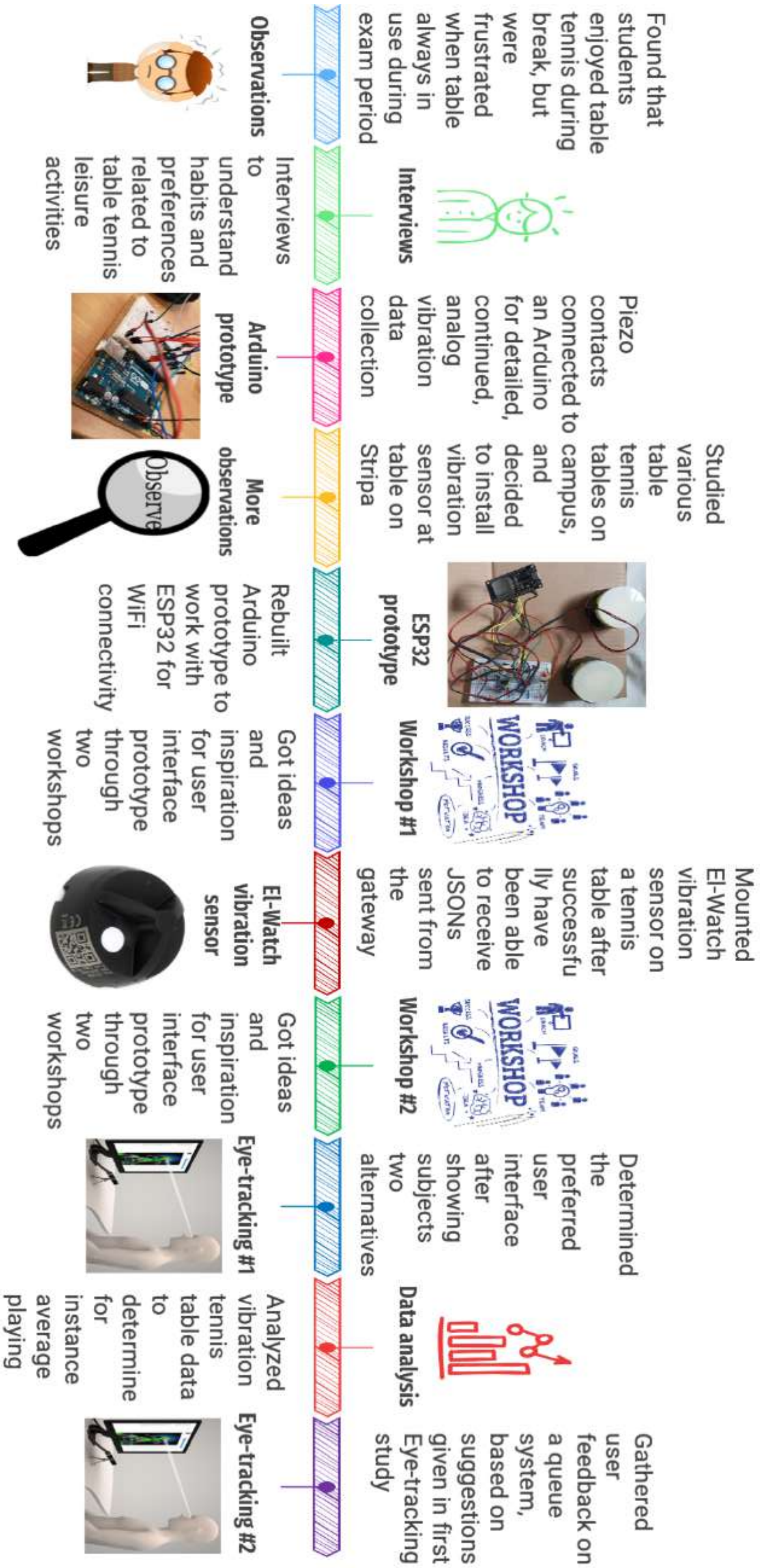


Figure 3.1.1: Timeline infographics of various data collection

(Photo credits: © artenot, © trueffelpix, © The EyeTribe, © Slidesgo)

Full-size timeline of figure 3.1.1 covering two pages can be found in appendix B.

The following section will briefly outline the timeline of methods conducted for this study, methods that will be expanded more thoroughly in subsequent sections. Having made the observation that students during the exam period find it annoying to leave their workplace for an activity break, only to find that the tennis table is occupied, the idea was born to monitor table activity using vibration sensors. Working hypothesis was that availability awareness through your cellphone or laptop would make it more convenient and less annoying to check availability through the use of technology. This observation was followed with interviews to map out habits and user preferences for playing table tennis, while at the same time building a vibration sensor sensitive enough to detect ping pong balls as they bounce on top of the table. In the early, exploratory phase, many forms of augmentation were considered. Research done in Germany showed many use cases made possible with a projector and a camera (Mayer 2016), in particular when practicing for something specific. It would for instance be possible to mark an area on the other side, fill the area with a color if the ball was successful in hitting that area. Other augmentation ideas included the possibility to use student identification cards for keeping track of scores. Both players would register before playing, and the winner got to scan the card again after the match. This would also allow for a table tennis ranking and make it easier to find other players at a similar level of playing skills.

Having done research on student groups that frequently played table tennis, contact was made with a group called Revolve NTNU. A very serious and dedicated group that make both a regular race car and an autonomous race car to compete in Formula Student. They are also serious about playing table tennis and logging every match using a dedicated computer. After each match they type in the names of those who played, with information about who won. This group was considered superb for data collection.

But first, the vibration sensor had to be built to determine if it would be possible to build a device that had enough sensitivity. Piezoelectric sensors were connected to an Arduino, and sure enough, it worked like a charm. Next challenge was to connect the setup to an internet connection. A regular Arduino has no WiFi support out of the box, so the piezoelectric sensors were transferred to an ESP32. The setup was now able to connect to the internet, and only remaining concern was how to supply power. An optimal solution for a tennis table would be to use battery as a power source, which also would be a better choice regarding fire safety.

Instead, vibration sensors and a gateway were provided by El-Watch (see chapter 4.2.2 for more details). The vibration sensors were small, had long battery life and connected easily to the tennis table with a magnet. In order to build a working prototype, a lot of work had to be done for figuring out how to receive vibration data from the gateway. The gateway had a built-in SIM card, which pushed vibration data to the cloud. To build a workable prototype, this vibration data had to be sent to a server using the JSON format, decoded and stored in a database. After a long struggle, decoding JSONs on the server and extracting vibration data became a success, and a simple user interface showing either a green or a red button was built.

Using the User Centered Design, requirements had to be specified. As part of the process of identifying user goals, more observations and interviews were conducted. After doing observations at many table tennis locations on campus, the decision for installing a vibration sensor at Stripa was made. Stripa is a long hallway, with lots of students passing through, featuring a highly visible tennis table.

Two workshops were done to collect ideas and inspiration for building a user interface prototype. One of the designs has been of a particular interest, describing a booking system in which a slot of 15 minutes is given if the table is accessible, and in the case of the table being taken then the user is asked to make a booking. In the end, for the purpose of doing a comparative study, two user interfaces presenting usage with 25 minute time slots were built. One user interface was inspired by the traffic light, and the other featured a graph showing recent activity. For data collection, permission was gathered from The Welfare Council for mounting vibration sensors underneath a tennis table in a student lounge next to the bustling Stripa. Vibration data from the publicly accessible tennis table at Stripa have been analyzed to determine for instance average playing time.

The two user interfaces were tested using eye-tracking and interviews, in order to evaluate the design. An iterative process followed, as feedback from this comparative study were used to make design improvements. It was determined that subjects preferred the graph interface over the traffic light interface, both for laptop and mobile devices. For future improvements, one subject suggested adding a queue system. The design was enhanced with minor improvements and a queue system. An updated graph design was evaluated again using eye-tracking and interviews.

3.2. Observations

To observe means “to watch” and “to pay attention to” (Oates 2005). Throughout campus there are tennis tables made accessible to the public, so it is easy to conduct observations. At Moholt Student Village there is a leisure and recreation area that has many exchange students. While they like to play regular table tennis, they have also developed their own style that is suitable for more people. A large number of rackets are available, so anyone can join. What they do is to run around the table, taking turns in who returns the ball, with the challenge being to keep the exchange going for as long as possible. A fun game even for beginners, since the nature of the game is more collaborative than competitive.

There is a tennis table outside the Abakus office, the student association dedicated to Computer Science, Communications Technology and Cyber Security master students, 3rd floor in the A-block at Realfagbygget. The Tihlde office is located in the same floor, the student association dedicated to computer science bachelor students, and students associated with Online, informatics bachelor and master students, also use the table – but they are located on the 4th floor, so it takes more effort to get there. Organized activities are limited to tournaments that Abakus does for its own students once per semester. During exams, play time can be virtually non-stop, so that it becomes nearly impossible for regular students to play just by randomly checking whether the table is available. Group size is typically not larger than 3, so that one student might be waiting while two are playing. The most visible and most accessible tennis table is at Stripa, next to Hangaren – the biggest cafeteria on campus, as part of a recreational lounge in the long hallway featuring board games, chess and Fußball.

Figure 3.2.1: Tennis Table next to Hangaren, Stripa

Here, students can make an impulse decision to play table tennis, as they walk by and have time available. Students can play for a few minutes during a 15-minute break, or for half an hour. Some students bring their own rackets. The more expensive rackets have a better grip on the ball, allowing for more trick shots. You'll see groups playing, taking turns, some play with points while others just pass the ball back and forth without bothering to count points. Those who are more competitive and do count points typically play longer.

Since November 2020 vibration sensors have been installed on this table, making it possible to detect if someone is playing or not. The vibration sensors generously provided by El-Watch (www.El-Watch.com) has a magnet, making them easy to attach at the bottom of the table. The sensors connect to a gateway that needs power in order to transfer data to the cloud. The gateway has a built-in SIM card. This setup makes it possible to analyze the data and generate descriptive statistics for when, and how long, the table is being used.

3.3. Interviews

A first round of interviews were conducted during fall of 2019, focusing on how a box with the ability to read student identification cards (as described in chapter 3.1) could enhance the experience of playing table tennis. Interviews were semi-structured, to allow for students to elaborate on questions provided, while still ensuring that the interview kept a certain theme (Oates 2005). In the interview guide, students are initially asked how often, on average, the student play table tennis, followed by a question of what needs to happen in order for them to enjoy playing table tennis more frequently. One student got really excited about this question, listing a number of ideas that would make table tennis more exciting. Like doing tournaments, fixed time slots, bronze/silver/gold league, matching with others who have time with inspiration from Tinder, setting up groups with different levels, enabling ranking lists for each student association with fame and glory to top 10, etc. A final question asked for their views on how to easily collect the score, and thoughts related to the use of student identification cards. The response was enthusiastically that it doesn’t become easier than that. Much easier than entering your name on a screen.

For a second round of interviews in the spring of 2020, interviews were more exploratory in nature – starting with demographic questions, then uncovering why the student play table tennis, feelings that arise when playing, frequency, location, etc. Interviews revealed that students play more during the exam period, because of more freedom and a need to take breaks from studying. Students confirmed that they would find broken equipment, which resulted in their hope for playing during a break ending in disappointment. Finding suitable partners to play with was found to be challenging, since many students have friends that are either better (typically more experienced) or with very little experience playing table tennis. Having results registered after each match was seen as a positive initiative, providing an overview and making it possible to keep track of own progress. Ranking was seen as fun, with the ability to match with other players and track own development after for instance one year. Proper equipment at all times would improve the experience of playing table tennis.

Additionally, introducing a system for matching players, through tournaments and other appropriate channels, so that one would get to play with more people and be exposed to a greater variety of playing styles. Better distribution of tennis tables was mentioned, so that students have better opportunities to actually play. The desire for live tracking was expressed, so that students would be able to investigate the availability of a table through the use of technology without physically needing to go there in person to learn if the table is available or not. Realfagbygget only has one tennis table, which was not deemed as sufficient by the interviewees for one of the largest buildings in Norway. Booking could help, but should be limited to 20 minutes so that the table also becomes available for others. Information about table availability should be shared at Innsida or Instabart. A graph with usage past hour or so would be interesting, but those interviewed expressed doubts about actual usage. Students were positive to the use a QR code, since it allows for easy access to the webapp, without the need to manually enter a link in the browser.

3.4. Workshops

In order to develop a better understanding of what potential users would like to see in an interface showing sensor data, students were invited to participate in a workshop. They were given information about the location of a tennis table at a place called "Stripa". A student lounge well known to NTNU students, with a central location and multiple leisure activities like chess, board games and Fußball. Participants of the workshop were informed about the collection of vibration data from the tennis table and asked to draw an interface on sheets of paper handed out at the workshop along with pens and colors. Two workshops were conducted. Results from the workshops are presented in chapter 5.2.

3.5. Eye-Tracking Usability Test

In order to evaluate two user interfaces, volunteers were invited to participate in an Eye-Tracking Usability Test. Half of the volunteers were presented first what the been termed the "traffic light" user interface, and the other half were presented the "graph" user interface. The “traffic light” user interface is illustrated below. Also code-named interface A. While the “graph” user interface is code-named interface B.

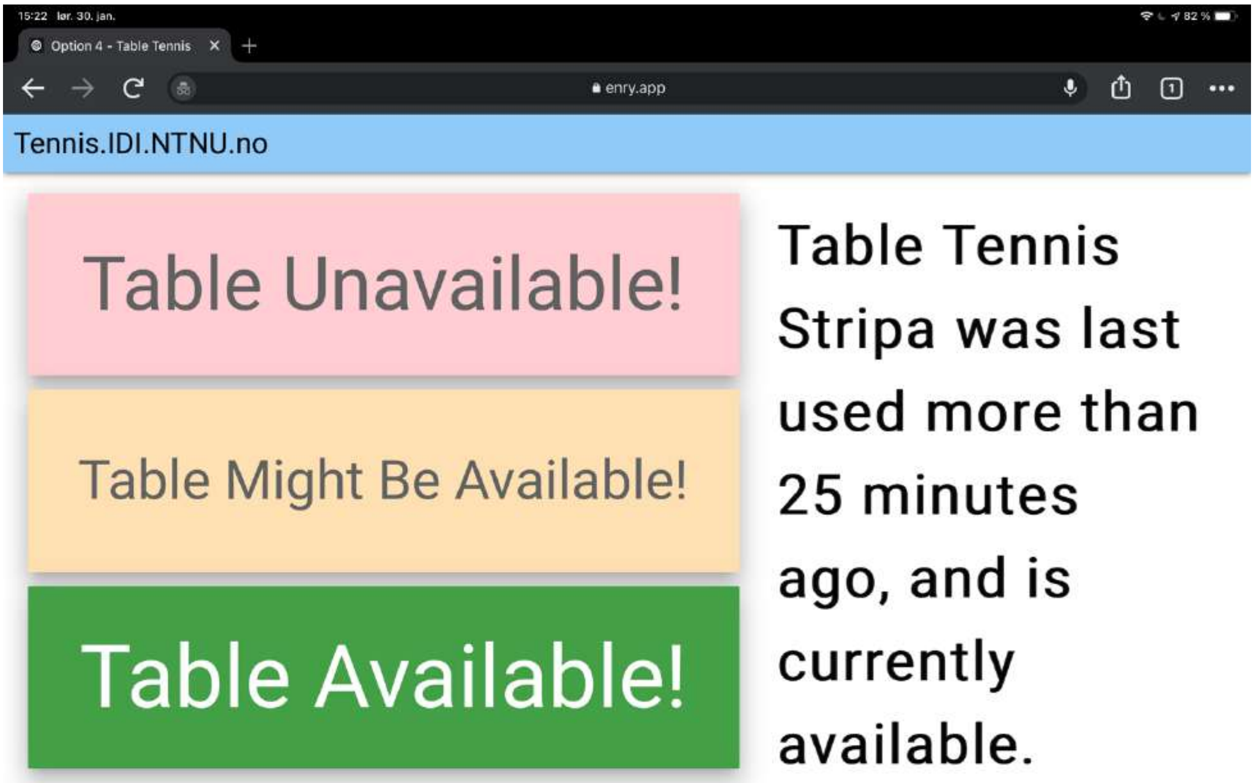


Figure 3.5.1: The “traffic light” user interface

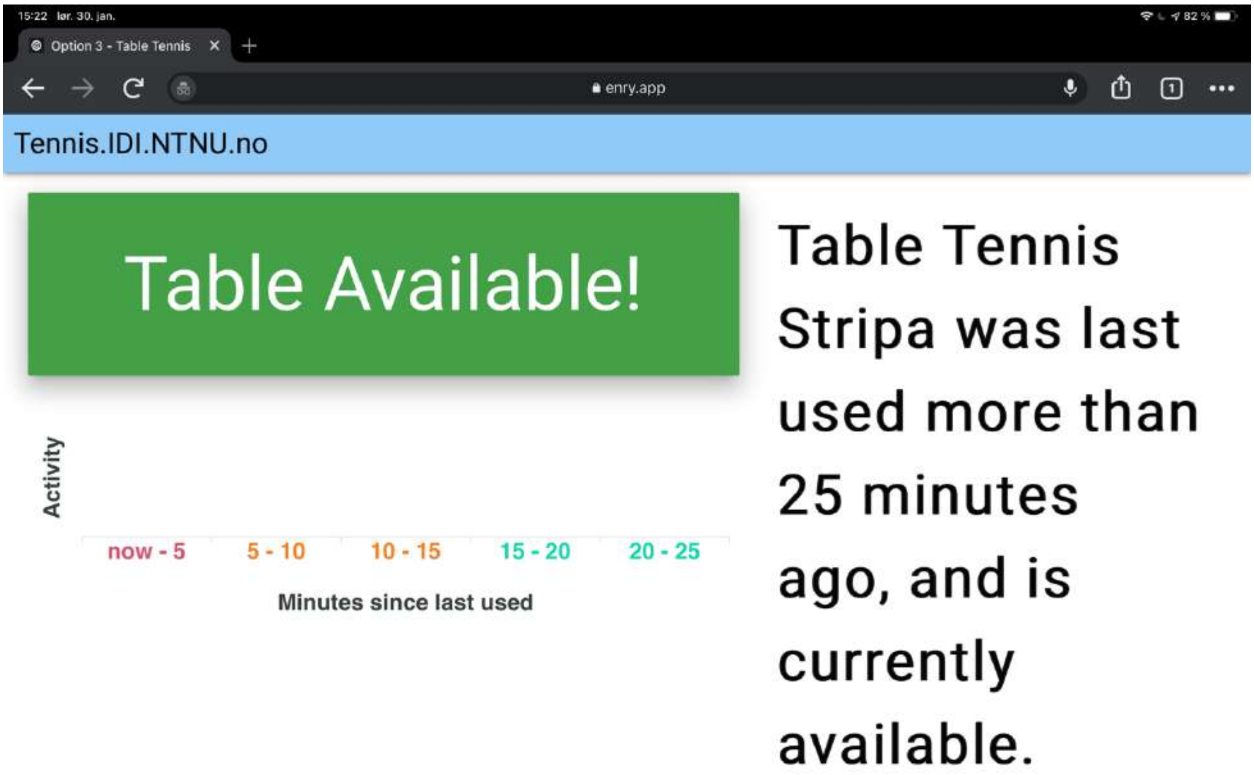


Figure 3.5.2: The "graph" user interface

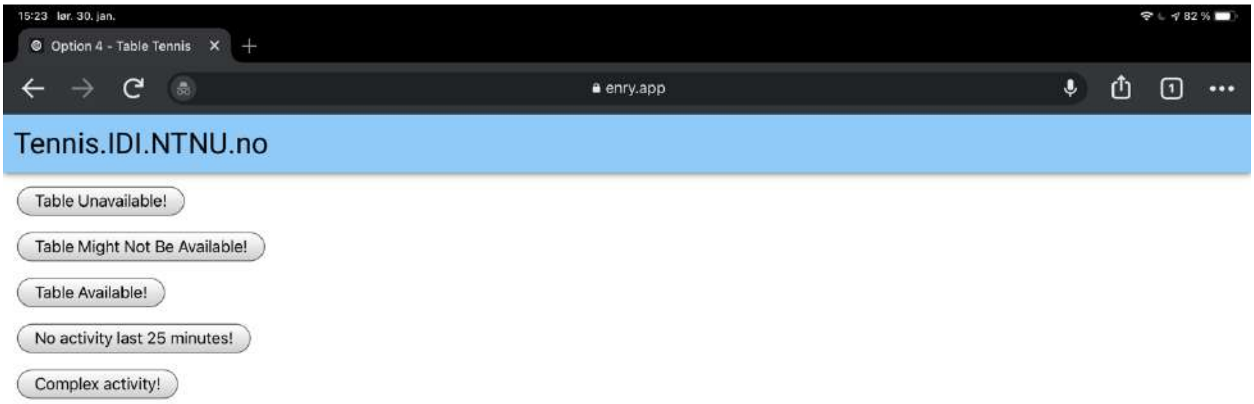


Figure 3.5.3: The control panel user interface

The volunteers would all start with an interface showing "no activity last 25 minutes", asked to speak out loud and describe what they see and understand. As time progress volunteers would all go through the same procedure. When "table available" were selected, the interacted showed that there had been activity at the table 20 minutes ago. "Table might not be available" updated the interface to show activity 10 minutes ago. And finally "table unavailable" would update the interface to show that the table have had activity last 5 minutes. The button becomes red with the text "Table Unavailable!". The final challenge is called "Complex activity" which is reserved for the “graph” user interface. It shows activity at both 10 minutes and 20 minutes. The volunteer is then asked to describe their understanding of what that means.

Tobii Eye Tracker were used in Eye-Tracking Usability Tests, which in addition to generating videos of where subjects are directing their attention combined with a webcam view in the lower corner, also generates heat maps. Heat maps aggregates all areas the subjects have looked at, showing areas that attract more attention as warmer.

3.6. Vibration data collection and analysis

Permission was given for installing vibration sensors at the tennis table located at the student lounge at Stripa. At least every two minutes, the database is updated. During vibration activity updates can be made as frequently as every two seconds, and each update is done with an extensive JSON. Which accumulates to a significant amount of data and a great number of data points. To analyze large amounts of data, the library Pandas and Python has been utilized. Before analyzing data, a number of steps were necessary to both strip away unnecessary data and ensure that all datapoints have the correct timestamp. When all preparations have been done, it is possible to extract descriptive statistics, like for instance what average playing time has been.

4. PROTOTYPE

In order to digitally augment the Table Tennis User Experience (UX) it was necessary to build a prototype. Piezo contact sensors were connected to an Arduino to establish proof of concept and later migrated to an ESP32 to reduce size and switch to a System on Chip with WiFi connectivity. A Trondheim based company named El-Watch later provided a vibration sensor and a gateway that made it possible to attach a sensor to tennis tables in public locations without the need for external power supply.

4.1. Architecture overview

With two possible sensors it became necessary to build an agnostic microservice able to collect data from any data source, store the data in any database, and pass on data to any frontend. First sensor was built using Arduino, later replaced with ESP32 and eventually an El-Watch system. Which included both a vibration sensor and a gateway. The system was deployed at a tennis table centrally located on campus. Data from the vibration sensor would flow through the gateway, to the Neuron Cloud, using REST calls to the backend. While the frontend uses REST calls to pull data from the backend using a microservice, as illustrated below.

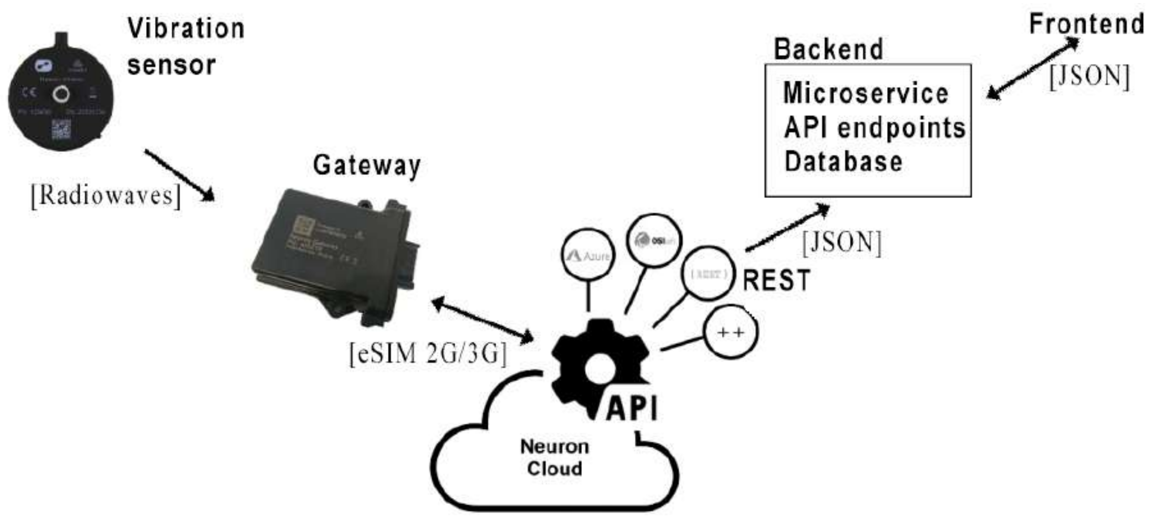


Figure 4.1.1: Architecture overview

Communication between frontend and backend is done with JSON through a microservice. The microservice is agnostic allowing data to be retrieved from any sensor and stored in any database. Communication from the Neuron Cloud to the backend is also done with JSON. The existing architecture give duplication in data storage and might at first glance seem redundant. While the Neuron Cloud has its own stand-alone interface, in order to build a custom interface with data from the vibration sensor, it is necessary to make this data easily accessible for the frontend. The Neuron Cloud store a lot of unnecessary data for each datapoint, so building a separate backend also facilitates data processing. The webapp frontend is built as a real-time application, allowing for faster updates with a local backend. The vibration sensor, gateway and the Neuron Cloud are components that cannot be bypassed. The only way to get data from the vibration sensor is through the Neuron Cloud API system. This architecture has chosen to pass on data using REST calls to the backed.

4.2. Components

In order to collect data, two piezo contacts were connected to an Arduino to test if that was suitable for measuring the vibration generated when a table tennis ball hits the tennis table. The Arduino Uno was later replaced with an ESP32 to reduce size and enable WiFi connectivity.

Later in the semester connection was made with a company in Trondheim that has 15 years of experience in the sensor industry, having built various types of sensors for use in the industry. They agreed to provide a vibration sensor and a gateway. The sensor uses a battery with a lifetime of many years, allowing for non-intrusive vibration measurement.

These sensors then connect to a backend that includes a microservice storing data in a database and pass on requested data to a frontend.

4.2.1. Piezo contact sensor

Initial version of the piezo contact sensors was built with Arduino Uno, as shown in the photo below:

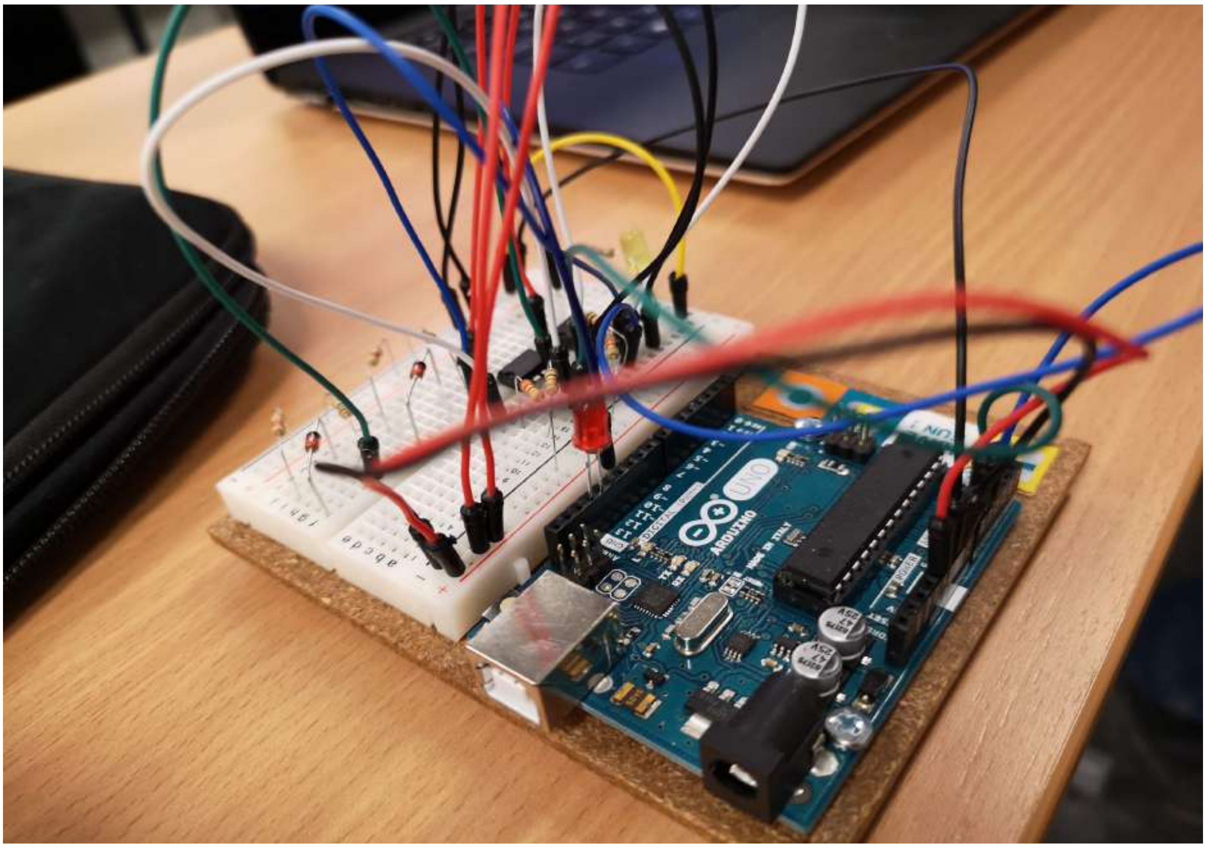


Figure 4.2.1: Two piezo contact sensors connected to an Arduino Uno

The Arduino Uno is an open-source microcontroller board. It is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards and other circuits. The board is programmable with the Arduino IDE (Integrated Development Environment), via a USB cable. For power, a USB cable or an external 9-volt battery can be used. Unlike Arduino Uno WiFi Rev2, the Arduino Uno has no WiFi capability.

Two piezo contact sensors were connected to the Arduino Uno. Breadboard and schematics for the setup of two piezo contact sensors connected to an Arduino can be found in appendix C.

The Arduino Uno has no WiFi capabilities, and instead of upgrading to it its successor Arduino Uno WiFi Rev2 to get WiFi support, an added benefit was achieved by replacing the Arduino with the much smaller ESP32. As shown below the ESP32 is much smaller than the Arduino Uno, and it comes with WiFi capabilities as well. While the hardware architecture is totally different, the company producing the ESP32 have made a solid effort writing software which bridge the hardware gap between the ESP32 and the Arduino. It is also possible to use the Arduino IDE as the development environment. About 90% of the Arduino libraries work with no modification when writing software for the ESP32. In addition to WiFi capabilities, the ESP32 also features Bluetooth support, it has more memory than the Arduino Uno and it is faster.

While vibrations could be detected in real time, at high accuracy, with the ability to define threshold levels, etc. a major challenge would be how to power the setup. There were many concerns with bringing a power cable underneath the table, like people tripping on wires, gathering the necessary permissions, and optimizing for power usage, would be outside the scope of this thesis. Setting up a car battery would be big, bulky and heavy, providing its own sets of challenges.

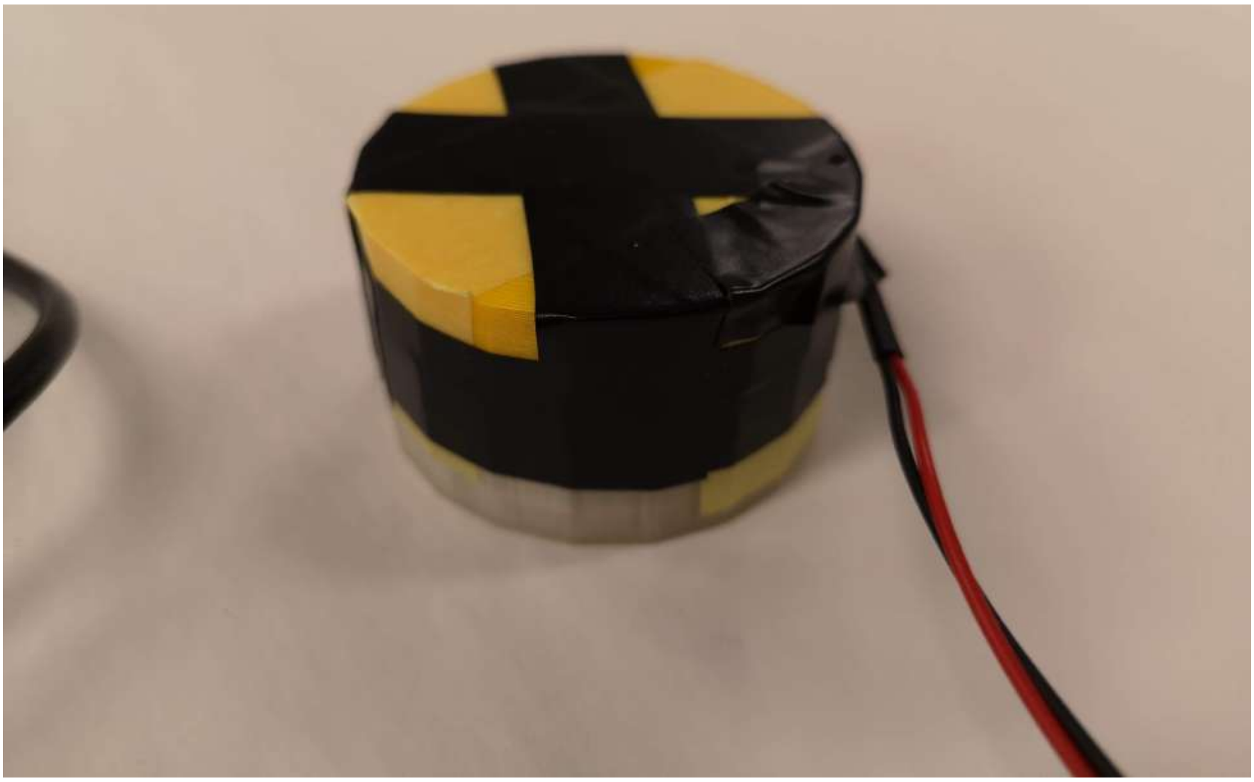


Figure 4.2.2: Piezo contact sensor

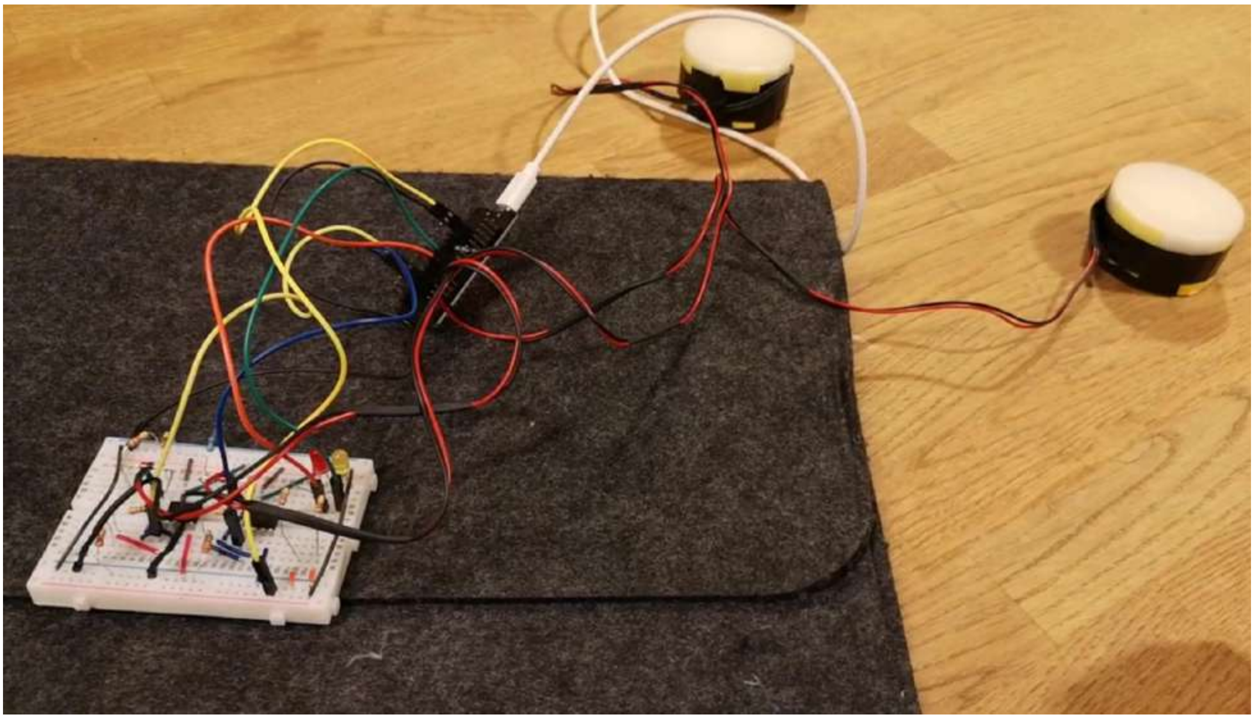


Figure 4.2.3: Two piezo contact sensors connected to an ESP32

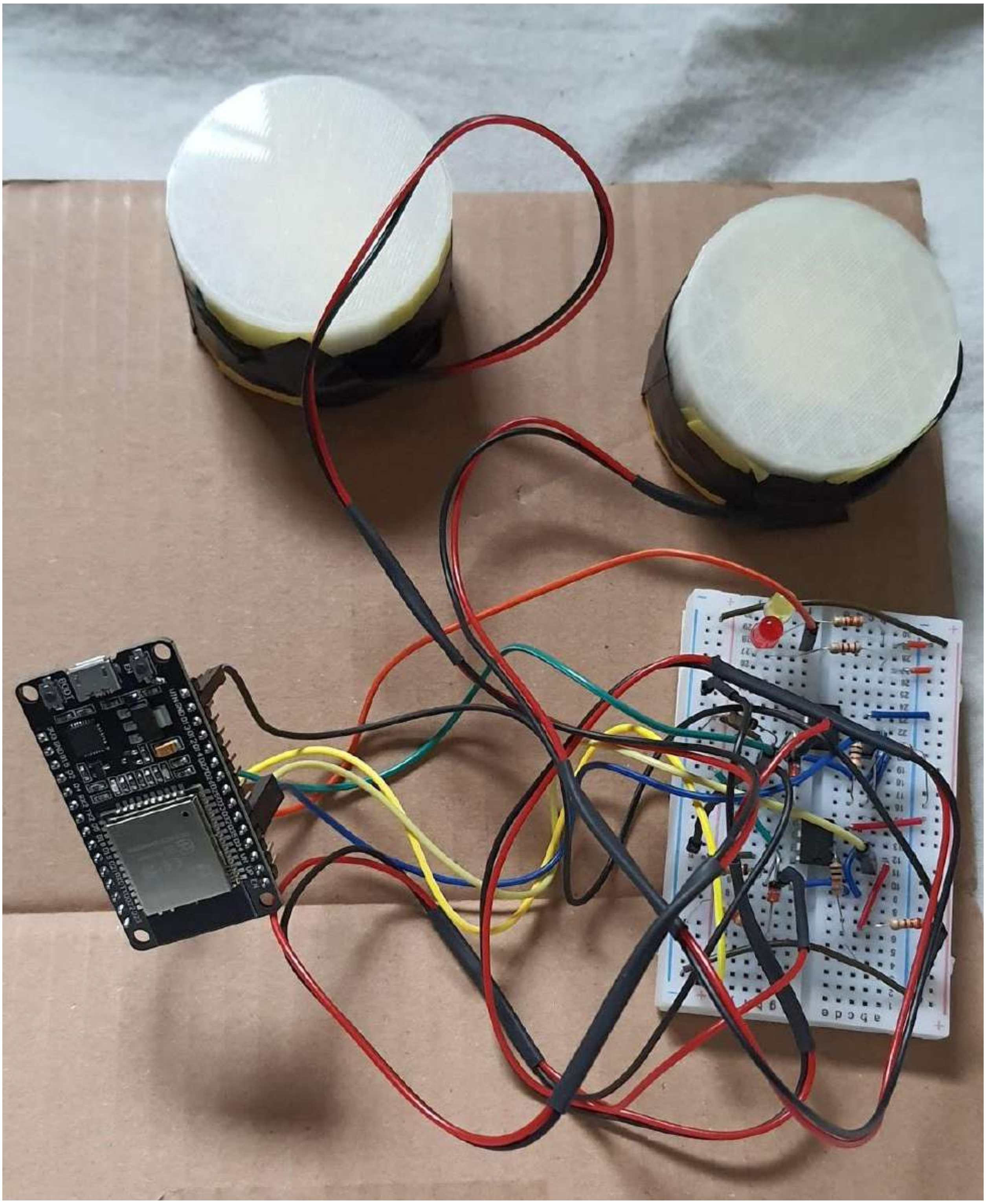


Figure 4.2.4: Two piezo contact sensors connected to an ESP32

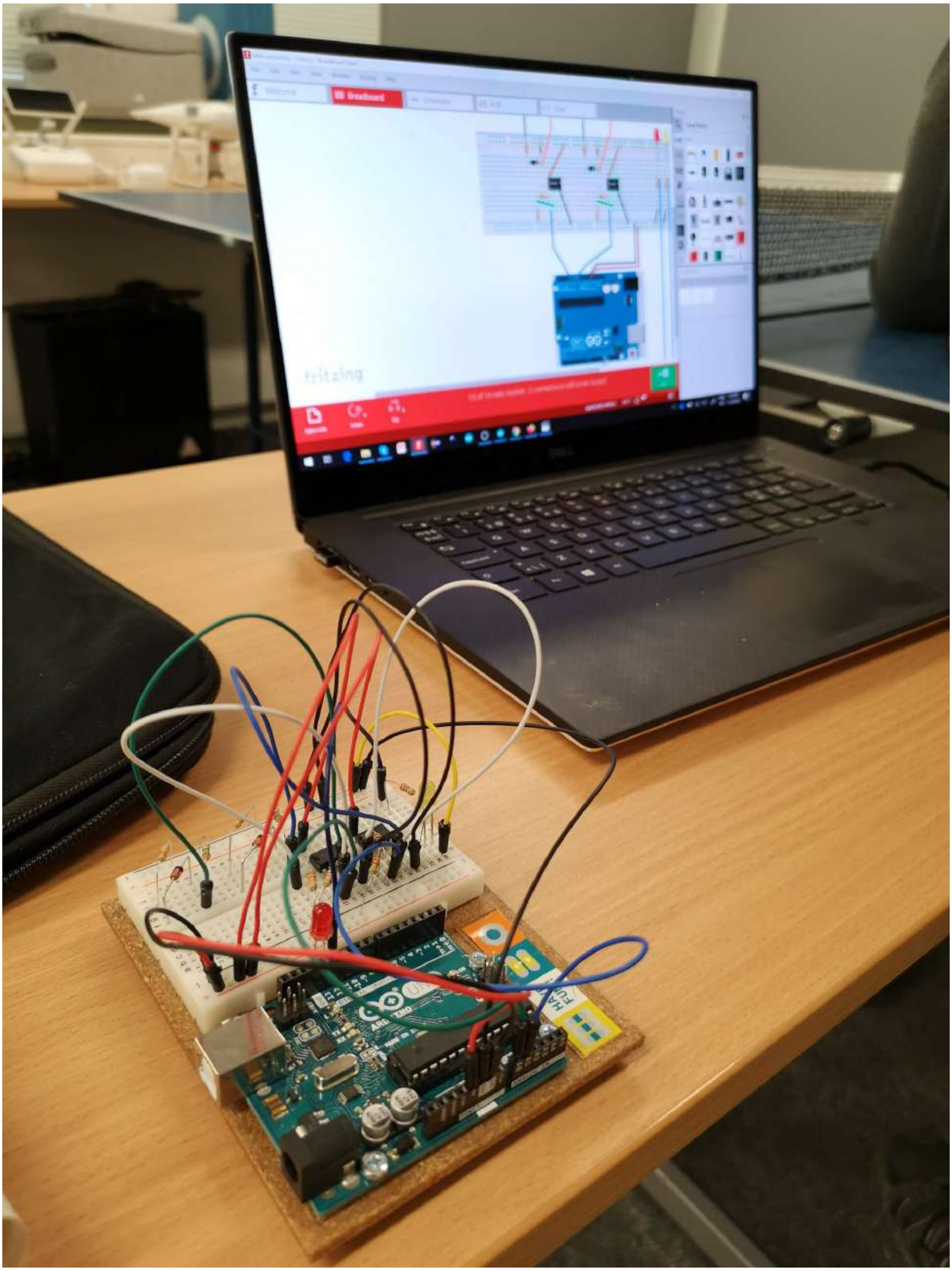


Figure 4.2.5: The Arduino Uno with fritzing and a tennis table in the background

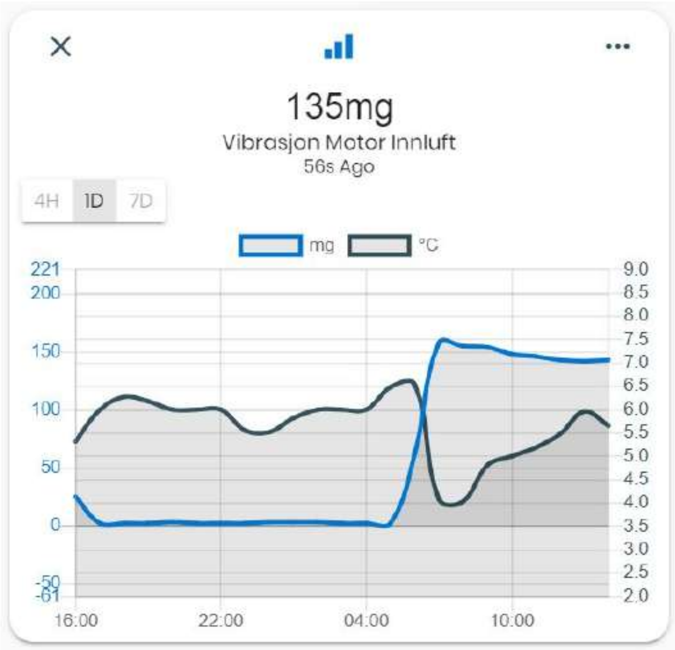
4.2.2. El-Watch vibration sensor

El-Watch has developed a wireless sensor system called NEURON, which features a vibration sensor as illustrated below.

Figure 4.2.6: Vibration sensor mounted on a wall (El-Watch Website 2020) and vibration sensor mounted on tennis table using a magnet (right picture)

Neuron Vibration is a robust sensor by El-Watch designed for industrial use. By attaching it to an engine (as illustrated below) it can for instance measure every 2 minutes what the vibration level is, and thereby detect abnormalities or malfunction. The sensor comes with an embedded magnet for easy mounting, and the integrated battery provides ten years lifetime. The sensor measure vibration in the range 0 - 12 g rms acceleration (sum of X, Y and Z axis) with a resolution of 0.001 g. Operating Frequency is 868 - 870 MHz when communicating with the Neuron Gateway. Data is transmitted to the Neuron Cloud via the Neuron Gateway.

While Neuron Vibration sensor is weather robust, as it should be when designed for industrial use, one drawback is the battery cannot be replaced. Initial version provided by El-Watch was configured to a higher reporting frequency than the standard 2 minutes, which also caused it to drain the battery faster. Since the battery could not be replaced, new sensors were provided.



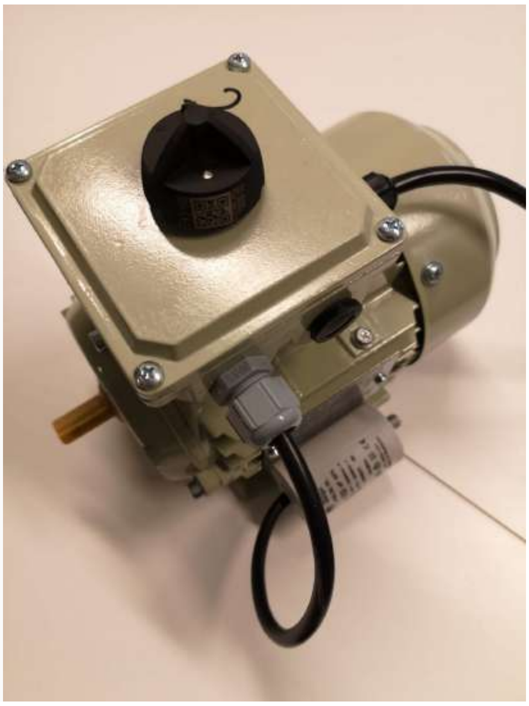


Figure 4.2.7: Screenshot of visualized sensor data and vibration sensor mounted on an engine (El-Watch Website 2020)

The Neuron Gateway has a built-in SIM card and is used to broadcast the vibration information to the cloud. The system supports both API calls and an integration for real-time data, so that for instance a microservice can receive updates in a JSON format on a regular basis and when the sensor picks up vibration.

The NeuronSensors cloud service is by default configured to give alerts when the Neuron gateway goes offline due to for instance power outage. While it is possible to define threshold levels in the NeuronSensors cloud service, to trigger alerts when detected vibration goes above a certain level, there is no obvious way of being alerted of vibration sensors coming out of range. Summer 2021 Sit student services decided to give away the tennis table which had a shovel to support the net on one side. Unaware of small vibration sensors being attached to the tennis table, those were also given away. Some detective work were required in order to retrieve the vibration sensors, and an alert has been configured to shorten the recovery time should something similar happen again. Figure below show that the service will send an email if vibration remains below 0.1 g for 24 hours. On any given day, including weekends, the table is used at least once.

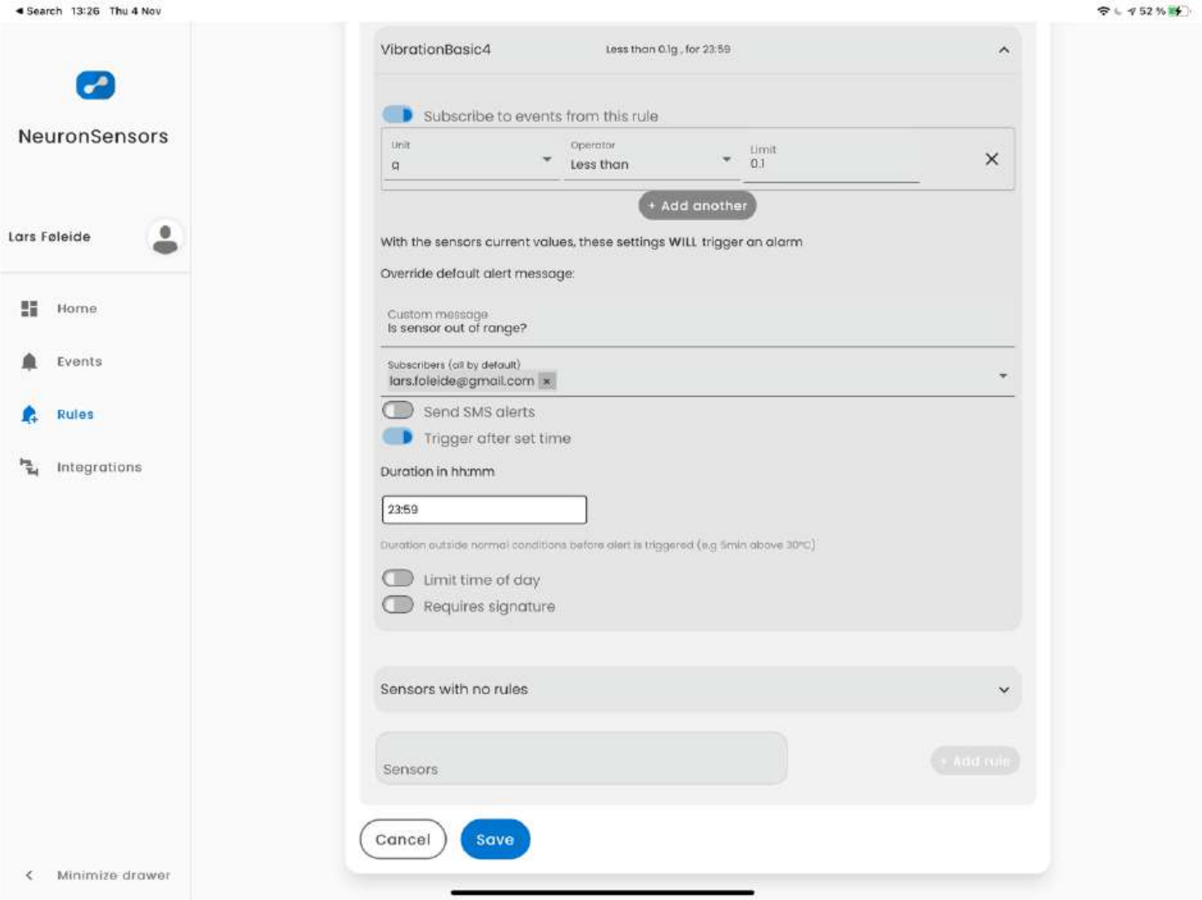


Figure 4.2.8: NeuronSensors cloud service dashboard

4.2.3. Microservice

The benefit of building a microservice is that there is no need to hardcode in the frontend how to retrieve data, and to hardcode in the backend where you store incoming data. As the effort to build a prototype capable of detecting vibrations evolved to include a third party vibration sensor, two possible sensors made it necessary to build an agnostic microservice capable of collecting data from any data source. A great benefit of introducing a microservice in the architecture is the ability to store data in any database and pass on data to any frontend. The microservice is built on the REST API principle. A service that is operational 24/7, ready to provide the frontend with requested information. It serves as a bridge between the data stored in the backend and the frontend, pulling data from the database, and serving it to the frontend. The frontend requests data using REST API calls. Since the microservice operates as a bridge between the frontend and backend, how the data is stored in the backend can be effortlessly changed, without needing to do any changes in the frontend code. Through an Application Programming Interface (API) the microservice becomes a service layer that abstracts away all backend services and dependencies. So that endpoint code accesses functionality rather than systems. The role of the microservice as a gateway API allow for easy access to data needed by the current frontend webapp, with the possibility to update microservice functionality to support for instance a native mobile app frontend, which might require more detailed data or data in a different format. The end result is a fault-tolerant microservice that is safe and allow for efficient development of concurrent code.

4.2.4. Backend

The backend was written in Flask, a mini framework built using Python. It uses an API (Application Programming Interface) to communicate between the backend and the frontend. For storing data, Cloud Firestore was chosen. The backend is continuously listening to REST calls from the Neuron Cloud and store the data in the Cloud Firestore. The Cloud Firestore database can easily be replaced with other databases like for instance MySQL and PostgreSQL. Cloud Firestore is a hosted database service provided by Google Firebase. It is a flexible, scalable NoSQL cloud database to store and sync data for both client- and server-side development. Like Firebase Realtime Database, it keeps data in sync across client apps through real-time listeners and offers offline support for both mobile and web. Making it possible to build responsive apps that work regardless of network latency or internet connectivity.

Initial prototype was done with Cloud Firestore and React, a stack normally used for bigger projects. Loading time was slow, so it was replaced with Flask and jQuery to make everything smaller and leaner while still retaining real-time application features. When doing web development there is an established stack called LAMP (Linux, Apache, MySQL, PHP/Perl/Python). An acronym with the P including both PHP and Python. While PHP works effortlessly with both the web server Apache and NginX, the language is to a large degree considered outdated, just like Perl is considered outdated, compared to Python and its rise in popularity. A large portion of the scientific community has embraced Python because of the many libraries that allow for analysis of large datasets, and prior experience made Python a preferred choice. In order to use Python web applications, it is necessary to set up what is called a Web Server Gateway Interface (WSGI). A specification that describes the communication between web servers and Python frameworks.

A more commonly used Python framework is Django, but that would make the backend overly complicated since it includes much that were not needed for this project. Django is a high-level Python web framework for rapid development and a clean, pragmatic design. While Flask is a mini Python web framework making necessary components easily accessible, and its size promotes a fast web application with minimal loading time.

Going for an SQL database would be convenient, given prior experience, but it was deemed not a suitable choice for this project. SQL databases are table-based databases whereas NoSQL databases can be document based, key-value pairs and graph databases. SQL databases are relational whereas NoSQL databases are non-relational. SQL databases require a predefined schema, while NoSQL databases use dynamic schema for unstructured data. SQL programming can be effectively used to insert, search, update, delete database records. NoSQL stands for “Not Only SQL”. NoSQL is non-relational that does not require a fixed schema, avoids joins, and is easy to scale. A popular choice for big data and real-time web apps. NoSQL scale better than SQL databases, and already with just one tennis table a lot of data is being stored in the NoSQL database with updates at least every two minutes. The Cloud Firestore is also a hosted database, simplifying database maintenance and allowing for a high uptime.

4.2.5. Frontend

By making REST API calls to the microservice, the frontend gets the information it needs to build a user interface. An alternative approach is to pull information directly from the backend database, which creates a myriad of problems should there arise a desire to replace the backend database storage solution or an upgrade to the backend service that is not fully backward compatible. This is solved through the use of a microservice as an intermediate. REST API calls to the microservice allows for it to serve as a mediator between the frontend and web services it seeks to pull information from. An added benefit is that resources and information can be shared while maintaining security, control, and authentication — determining who gets access to what. Initially React was used to build the frontend, but loading time proved not to be fast enough, so the solution was scaled down using jQuery instead of React. The interface just needs updates of what has happened the last 25 minutes in order to update contents. Since the graph has been divided into 5 minutes intervals, the only information the frontend needed to retrieve from the microservice was a JSON with 5 digits:

```
{"results":[0,1,0,1,0]}
```

It follows a binary system, with 1 indicating activity during a 5 minutes interval and 0 indicating no activity. In the example above, the table would be available since there has been no activity last 5 minutes. It is described as "complex activity" and used to test if subjects understood information presented in the graph. The second digit represent the interval 5-10 minutes, which is shown as active. Followed by a 5 minutes interval with no activity, and then activity last 15-20 minutes. 20-25 minutes had no activity.

The user interface uses jQuery to ask for this JSON every 5 seconds, and make updates to the user interface that match content of the JSON. Which include updates to the text, updates to the graph and updates about the table being available or not. Availability is indicated with both text and the background color green. While the table being unavailable is indicated by text and the background color red.

With the introduction of a digital queue system, the microservice was updated to include the number of people waiting in the JSON and information about joining the queue was sent to the microservice. An update would also be sent to the microservice if remaining time in the queue was extended.

4.3. Prototype Development

The first prototype was an Arduino device with piezo contacts. It was tested on a tennis table and found to be sensitive enough to detect the impact of a ping pong ball bouncing on top of the table. Next challenge was connecting the prototype to the internet, which wasn't supported out of the box on this Arduino device since it didn't have WiFi connectivity. The Arduino device was also quite large, so it was replaced with a much smaller ESP32 that comes with built-in WiFi support. Many more challenges remained, for instance how to power this device underneath the tennis table and challenges related to analysis of the data. These were discussed with supervisors in weekly meetings. Solutions were proposed and during this process permission was given to mount vibration sensors on the tennis table at Stripa, a highly trafficated stop on campus. With the goal of collecting vibration data from a tennis table in a densely populated and public recreational area on campus, a great number of possible challenges became real with regards to fire hazard and the possibility of student tripping on wires going to the tennis table if a wired power solution became the preferred solution. The campus janitor could object to any proposed solution, on the sole basis that the setup would be homemade. And getting into the whole battery powered solution would make it tempting to optimize the device for power consumption, which we agreed would be beyond the scope of this study. At the same time, installing a car battery seemed a bit excessive.

MQTT (MQ Telemetry Transport) became the choice of messaging protocol, which presented a new challenge. The ESP32 needed to connect to an open WiFi network for MQTT to work, and it was not possible to configure the ESP32 such that it would connect to the campus-wide WiFi network Eduroam. In weekly meetings with supervisors, information was given about a workaround to the issue, so that once the device was ready to go live, it would be possible to authenticate it to work on the network.

What allowed for a shift of focus away from hardware towards software was a gracious gift from El-Watch which included both a vibration sensor and an internet gateway. A gateway with a built-in SIM card, which presented itself as a satisfactory solution to allow for efforts to be concentrated using user centered design to develop and test possible user interfaces. And additionally, focus on other aspects such as data collection and data visualization. The vibration sensor was small, sturdy and came with a magnet, making it easy to mount underneath the tennis table. With its long range to the gateway, the gateway could easily be mounted out of sight and possible interference to the ongoing collection and reporting of vibration activity at the tennis table. How sensors communicate through the gateway to the Neuron Cloud is illustrated in a figure below.

While it was easy enough to plug the gateway to power and see through the Neuron Cloud that the vibration sensor indeed detected vibrations, it was an entirely different story to integrate data from the system with a custom built user interface. The Neuron Cloud system can be configured to send a JSON (REST call) whenever it detected vibration, sending an update at least every two minutes.

The ability to collect and read JSONs was initially tested with the service RequestBin.com, a specialized service to collect, inspect and debug HTTP requests and webhooks. RequestBin.com provides a URL that collects requests being sent to it, for inspection in a human-friendly way. It integrated well with the Neuron Cloud service. Later an integration was made with a homemade server running NginX. To support the use of Python, the server was set up with WSGI (Web Server Gateway Interface) for communication between NginX and Python. With the exception of a few power outages on campus, the setup has maintained a solid uptime.

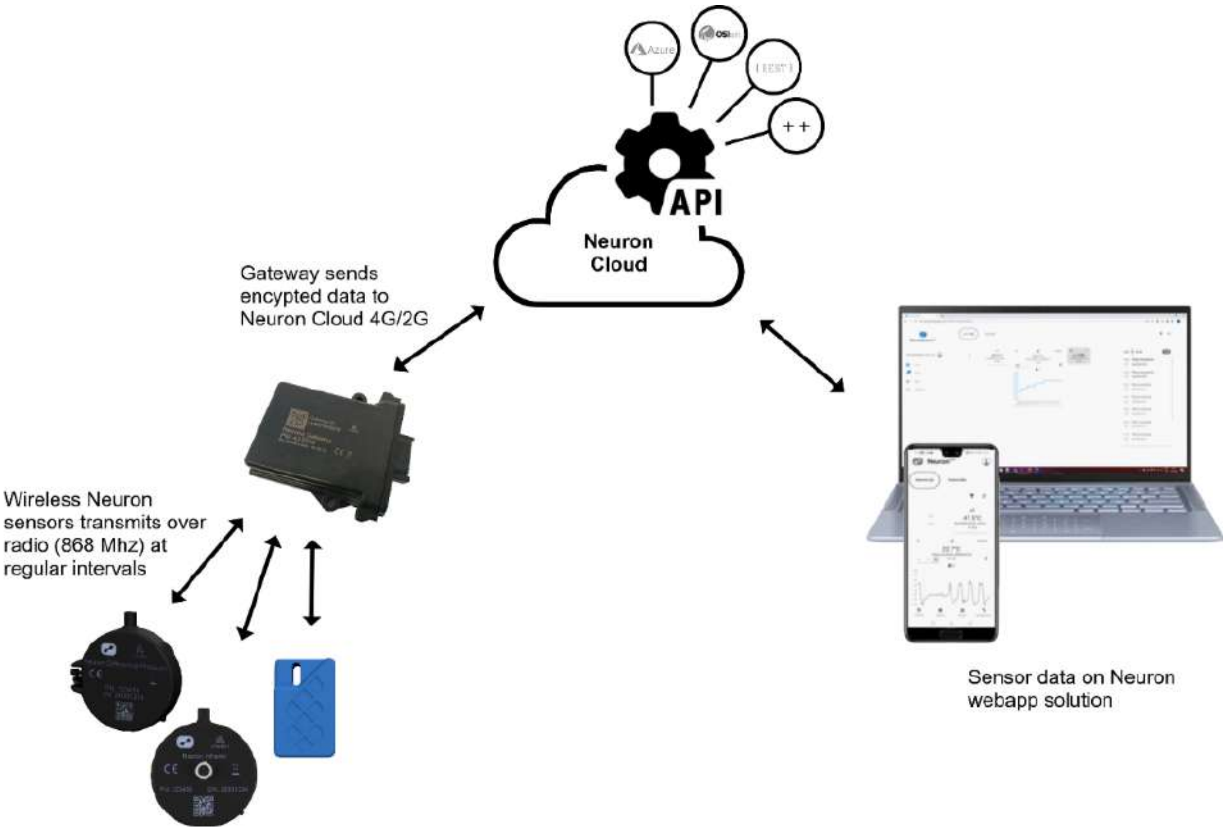


Figure 4.3.1: How sensors communicate through the gateway to the Neuron Cloud (El-Watch Website 2021)

5. RESULTS

This study required prototyping with both hardware and software. To achieve a privacy and anonymity preserving system where the added features are as non-intrusive as possible, we needed to consider other approaches than cameras and computer vision. An Arduino device was therefore built with piezo contacts mounted underneath a tennis table to determine if the setup would be sensitive enough to detect vibrations caused by a ping pong ball. In parallel, efforts were made through observations and interviews to develop a better understanding of the relationship students had to table tennis. The study has employed a User Centered Design approach, in which understanding user requirements is important. To better include users in this iterative process, two workshops were conducted to gather input for the user interface.

5.1. System Requirements

Following the User Centered Design approach, observations, interviews, and workshops were done to understand and specify user context, and also to specify user requirements (as illustrated below). For building a system that meet system requirements, information gathered during initial steps were used to build various user interfaces. For producing design solutions that meet user requirements, two were selected for evaluation. During eight eye-tracking sessions, subjects were asked to explain their understanding of system behavior during various scenarios for both user interface designs, followed by an interview discussing pros and cons of the two interfaces and questions related to usage and possible improvements.

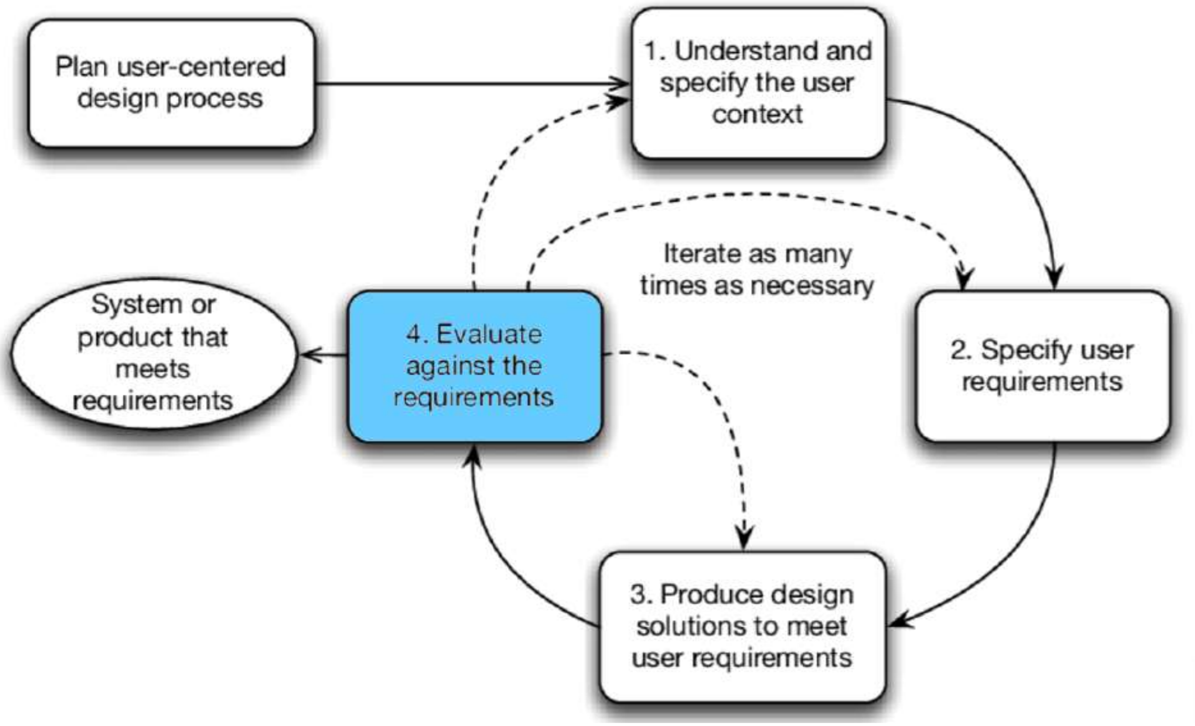


Figure 5.1.1: User Centered Design approach

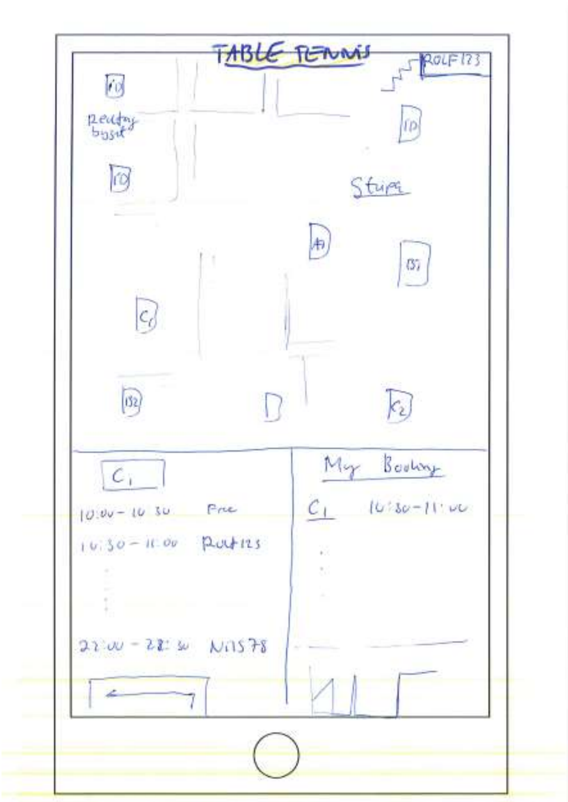
During the fourth step, evaluation against the requirements, subjects expressed a preference towards a queue system. When asked about the possibility of expanding the user interface to include a booking solution, one subject expressed a preference towards a queue system rather than booking. Much like what the new and innovative hair cutting service Cutters (www.Cutters.no) provide for their customers.

Which gave rise to an iteration according to the User Centered Design approach, as user requirements were updated, and the design were updated to feature a queue system (see chapter 5.4). Step four, evaluation against the requirements, were then repeated with five subjects to test if the design solutions met user requirements and then make necessary improvements before reaching a system that meets requirements.

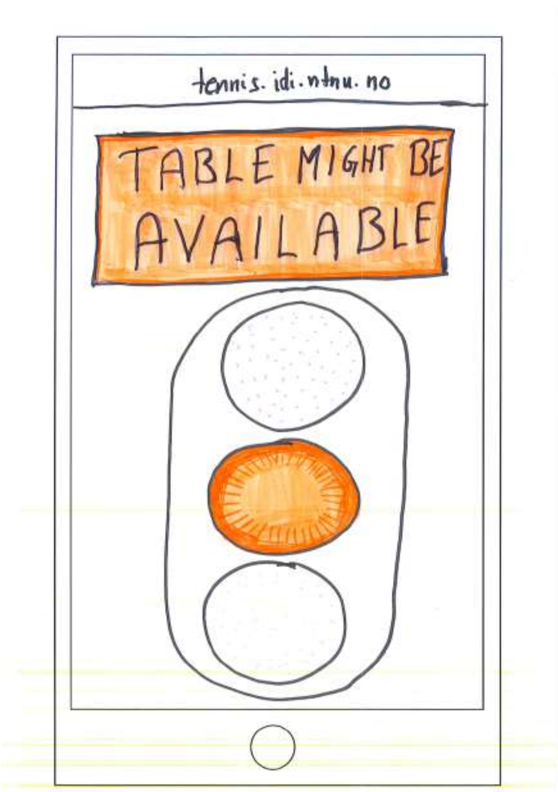
5.2. Workshops

Two workshops were conducted. During the workshops students were given information about the location of a tennis table at a place called “Stripa”. A student lounge well known to NTNU students. Participants of the workshop were informed about the collection of vibration data from the tennis table, and asked to draw an interface on sheets of paper handed out at the workshop along with pens and colors.

Results from the 1st workshop is shown in the figure below:

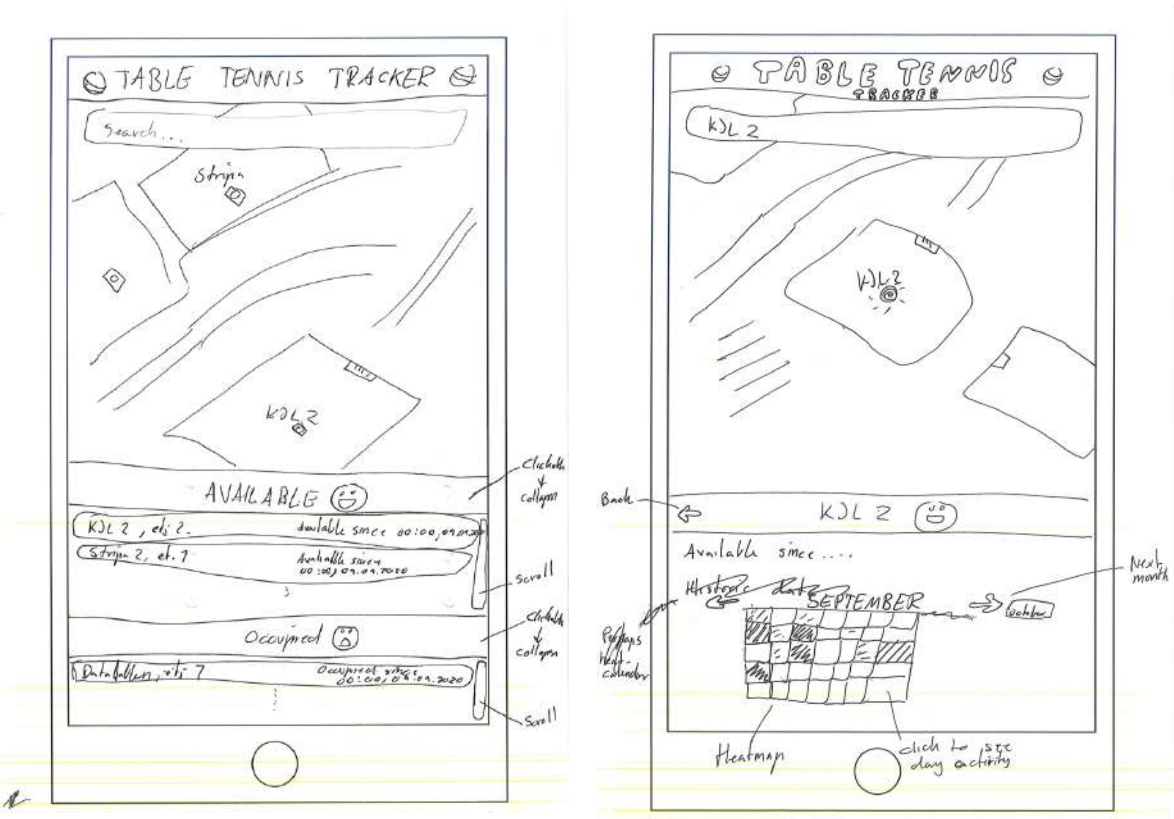


1)

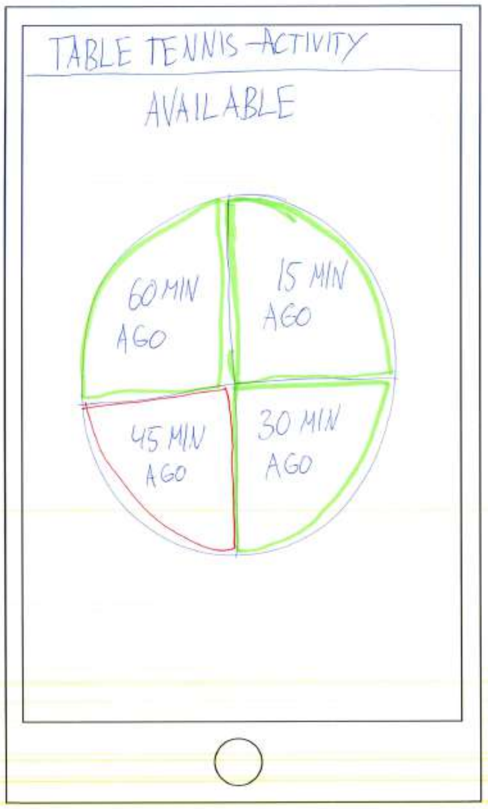


2)

Figure 5.2.1a: Design suggestions produced during workshop #1



3)



4)

Figure 5.2.1b: Design suggestions produced during workshop #1

The workshop showed a wide range of suggestions, varying from color coding to illustrate recent availability, to a map for locating available tables, and a booking system for reserving tables. The first design shows a user that is logged in with an active booking of table C1 between 10:30 and 11:00. The design shows that another user has a booking in the evening, and there is historical usage of the selected table C1 in the lower left section of the screen. The map shows all accessible tennis tables, and clicking on anyone of those will show available times, times that have been booked, and personal booking times will be shown irrespective of which table that has been selected. Second design is simpler. It uses color coding and text in the context of a traffic light to show that a specific tennis table "might be available”. Third design is shown with two screens. It features a search function, a map showing all tennis tables on campus, and lists of both available and occupied tables. It is possible to scroll through these lists, and they can be collapsed as well. When a table has been selected, a calendar of the month becomes visible with a heatmap. It is possible to click on the calendar to see day activity. Available tables have information about date and time the table was last used, and occupied tables include information about date and time the table became occupied. The fourth design also use color coding and show in sections of 15 minutes each if a table has been in use or not the last hour. The color green means no usage, while red means that the table has been used during the 15 minutes interval. In the example given the table had activity 30 to 45 minutes ago.

When discussing results with supervisors, feedback was given on the large area for drawing the various designs. An entire A4 page, way bigger than actual screen size on mobile phones. The decision was therefore made to conduct a second workshop, with more realistic screen sizes for participants to draw their design suggestions on. Each A4 paper featured four screens, making each screen similar in size to an actual mobile phone.

Results from the 2nd workshop is shown in the figure below:

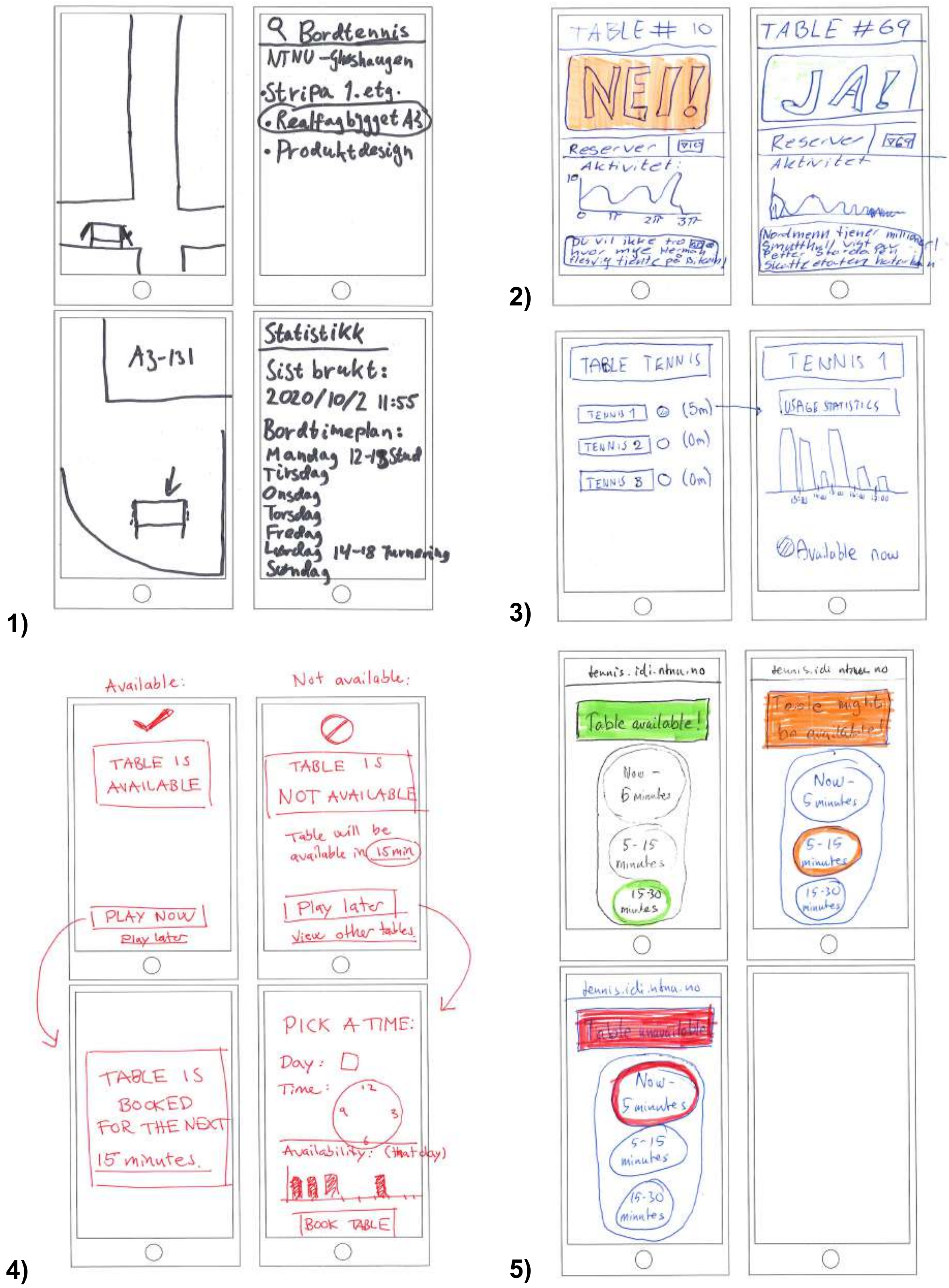


Figure 5.2.2: Five design suggestions produced during workshop #2

The reduced screen size gave more realistic design proposals. Proposal #1 showed a Mazemap integration, with the ability to get the location for each table in addition to statistics like last usage, and bookings ahead in time.

Second proposal featured a very explicit message about the availability of various tables, and the ability to make reservations. Third proposal featured two scenarios with a table being available and not, allowing for the table to be booked for 15 minutes. When choosing reservation time, it is also possible to review historical usage. The third proposal featured the use of symbols to signal availability as well.

Fourth design showed a list of tables and corresponding availability, with additional information about how many minutes had passed since last usage. A second screen also showed the ability to click on a table to pull up additional information about historical usage. Fifth proposal featured a traffic light interface, featuring 3 recognizable colors that intuitively show table availability.

Total number of workshop participants: 9

The table below show a summary of features that workshop participants chose to include. Everyone had some sort of availability awareness, 4 participants chose to include booking, 4 participants had usage statistics and 3 participants had a map.

	Number of praticipants
Map	3
Availability awareness	9
Booking	4
Color coding	3
Usage statistics	4

Table 5.2.1: Workshop summary

5.3. Low-fidelity and high-fidelity prototyping

Observations, interviews, and workshops allowed for user context to be understood and specified, and also to specify user requirements. This process allowed for both low-fidelity and high-fidelity prototypes to be developed, as illustrated below. When several prototypes had been developed, two were selected for evaluation to test if design solutions meet user requirements.

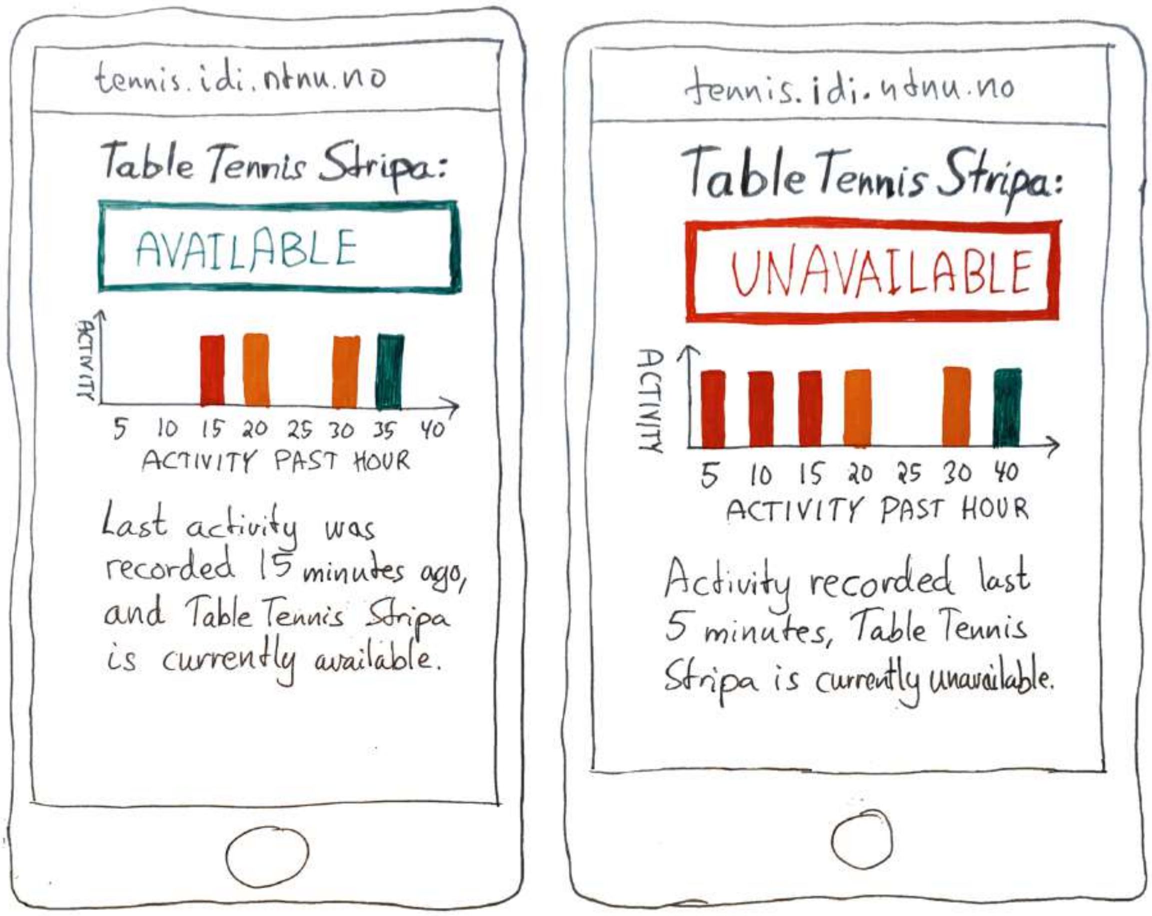


Figure 5.3.1: Low-fidelity prototype of user interface

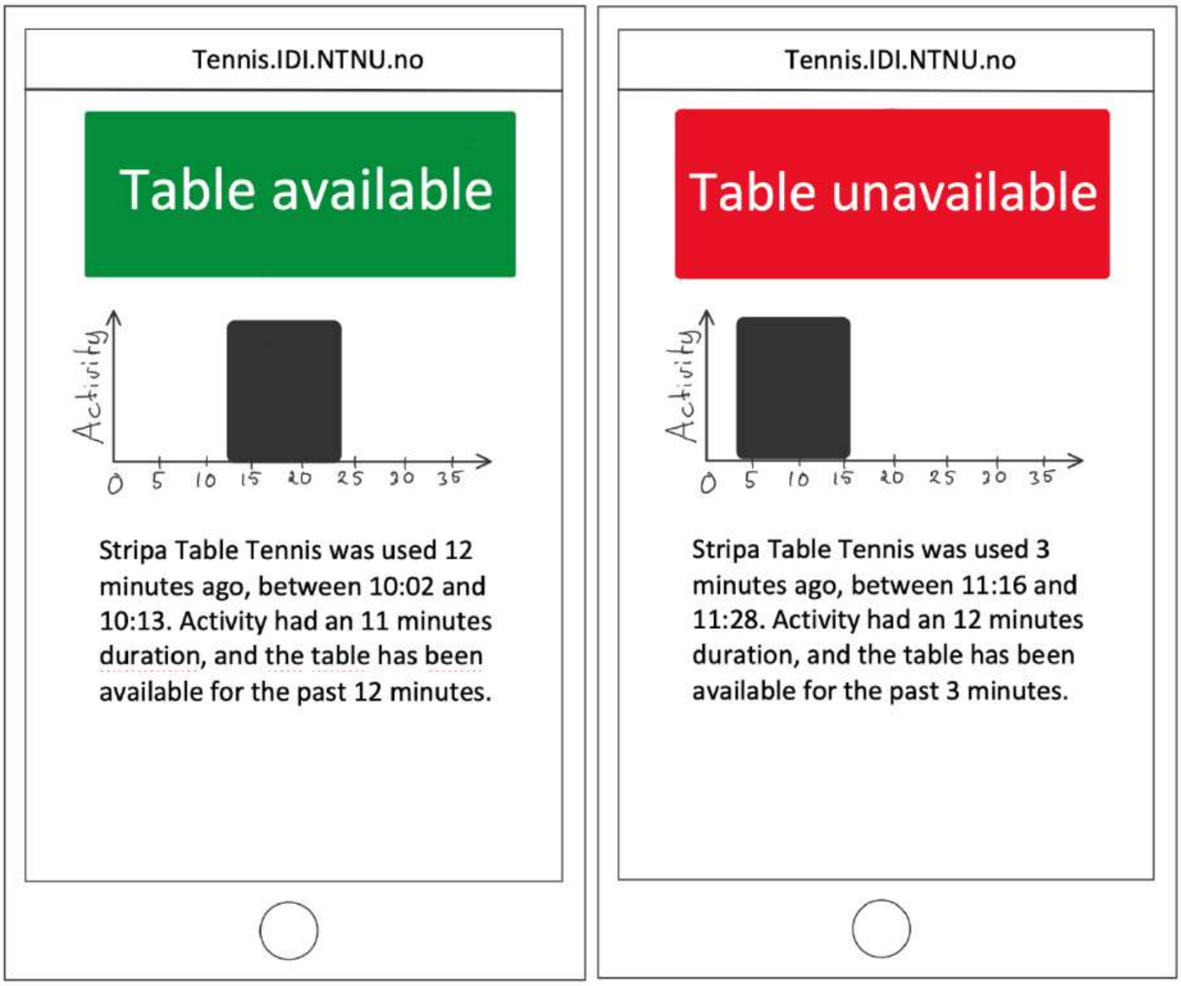


Figure 5.3.2: High-fidelity prototype of user interface

5.4. Vibration Data

Vibration data have been collected since November 2020, and while it is difficult to say something about what is “normal” during a pandemic, the data collected during the fall of 2020 came close. At that time there was no mask mandate in Trondheim, and there were still high activity levels at the tennis table, which is normal during the exam period.

The vibration sensor measure vibration in the range 0 - 12 g rms acceleration (sum of X, Y and Z axis) with a resolution of 0.001 g. Using a Python library called pandas, JSON files with vibration data could be imported and easily analyzed. Pandas makes it easy to generate new columns based on the underlying data, like showing the weekday in a column based on the datetime of the vibration data. The example below shows two weeks of vibration data (40525 data points).

	g	year	month	day	week	weekday	Weekday	hour	minutes	ones
datetime										
2020-11-10 22:14:29.986000+01:00	2.281	2020	11	10	46	1	Tuesday	22	14	1
2020-11-10 22:14:30.987000+01:00	1.786	2020	11	10	46	1	Tuesday	22	14	1
2020-11-10 22:14:31.987000+01:00	1.386	2020	11	10	46	1	Tuesday	22	14	1
2020-11-10 22:14:32.979000+01:00	1.548	2020	11	10	46	1	Tuesday	22	14	1
2020-11-10 22:14:33.975000+01:00	0.866	2020	11	10	46	1	Tuesday	22	14	1
...	...	...	...	...	...	...	...	...	...	...
2020-11-23 23:51:45.559000+01:00	0.030	2020	11	23	48	0	Monday	23	51	1
2020-11-23 23:53:45.871000+01:00	0.032	2020	11	23	48	0	Monday	23	53	1
2020-11-23 23:55:46.192000+01:00	0.038	2020	11	23	48	0	Monday	23	55	1
2020-11-23 23:57:46.521000+01:00	0.030	2020	11	23	48	0	Monday	23	57	1
2020-11-23 23:59:46.839000+01:00	0.041	2020	11	23	48	0	Monday	23	59	1

40525 rows × 10 columns

Figure 5.4.1: Vibration data from tennis table in table format

When a pandas DataFrame has been prepared, it is easy to create plots from slices of the underlying data. The command below shows vibration data from November 20th 2020 from 9:00 am until 22:00 pm, presented in a resampled format of two minutes. Which is why the y-axis can show more than 12 g, the maximum value of one data point. What pandas does is to bundle all values in a two-minute window, so that you get higher peaks when there is a lot of vibration activity. An accumulation of vibration during two-minute intervals.

```
s3[(s3["day"] == 20) & (s3["hour"] > 8) & (s3["hour"] <
23)].resample("2Min").sum()["g"].plot()
```

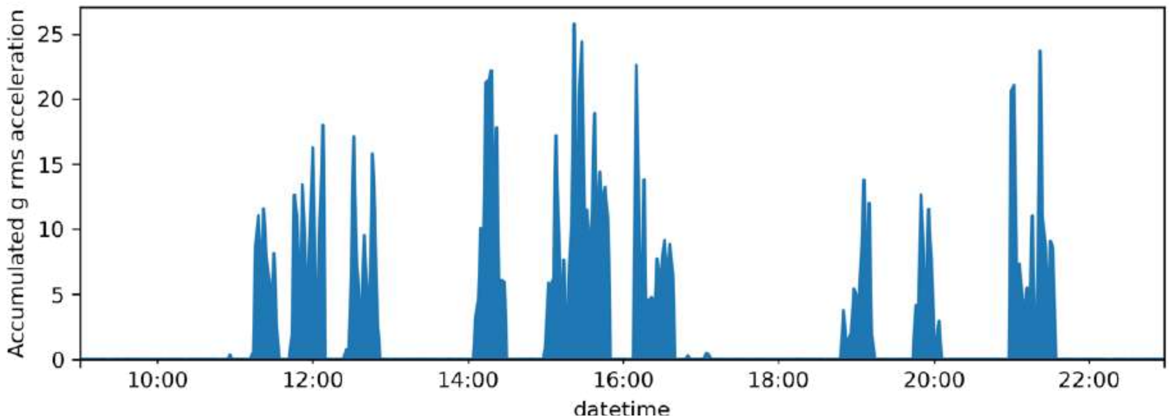


Figure 5.4.2: Vibration data from tennis table during November 20th 2020

When generating descriptive statistics from the collected vibration data, interesting insights can be extracted. Like for instance that the average playing time has been found to be 13 minutes and 20 seconds.

At a technology university like NTNU many students have an interest in data analysis and the analysis of data for making informed decisions. Making historical data accessible, beyond the last 25 minutes, is therefore expected to be a popular extension to the user interface. While analysis of vibration data can be used to generate descriptive statistics like average playing time, it is also possible to make graphics like the figure above accessible in the user interface. The exploration of historical data can also be made interactive by the use of JavaScript charting libraries like ApexCharts. Making historical data accessible in the user interface has been beyond the scope of this master thesis and is therefore part of future work.

5.5. User testing using Eye-Tracking

First eye-tracking study had a comparative setup, comparing a “traffic light” interface with graph interface (as illustrated below).

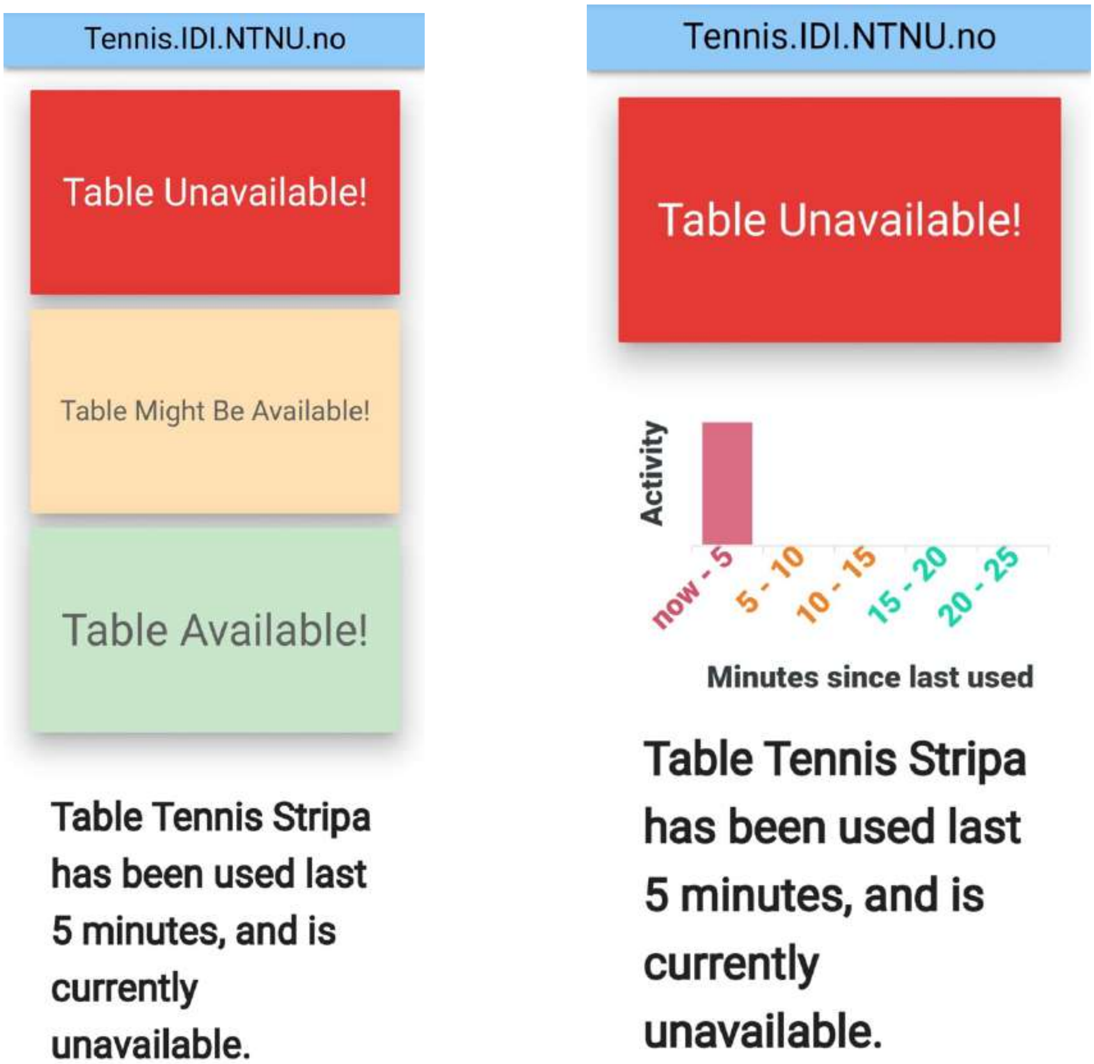


Figure 5.5.1: “Traffic light” and graph user interface

The figure above shows mobile view of the user interface, in which the text comes at the bottom as opposed to the right side in tablet and laptop view. Subjects expressed a preference towards the graph interface, especially after being presented the mobile view, which showed a better utilization of limited screen real estate. Text at the bottom was barely visible in the graph view, while you had to scroll to realize that there even was text at the bottom in the “traffic light” user interface.

Some subjects were confused by text shown during various scenarios, for instance:
"Table Tennis Stripa has been used last 20 minutes, and is currently available."
Which some understood as continuous use last 20 minutes, while what was intended to communicate was no activity last 20 minutes, thus making the tennis table available. In the queue user interface, wording now has been updated to:
"Table Tennis Stripa was used 20 minutes ago, and is currently available."

Which was the only additional change in addition to the new queue feature requested by users, in the updated user interface iteration:

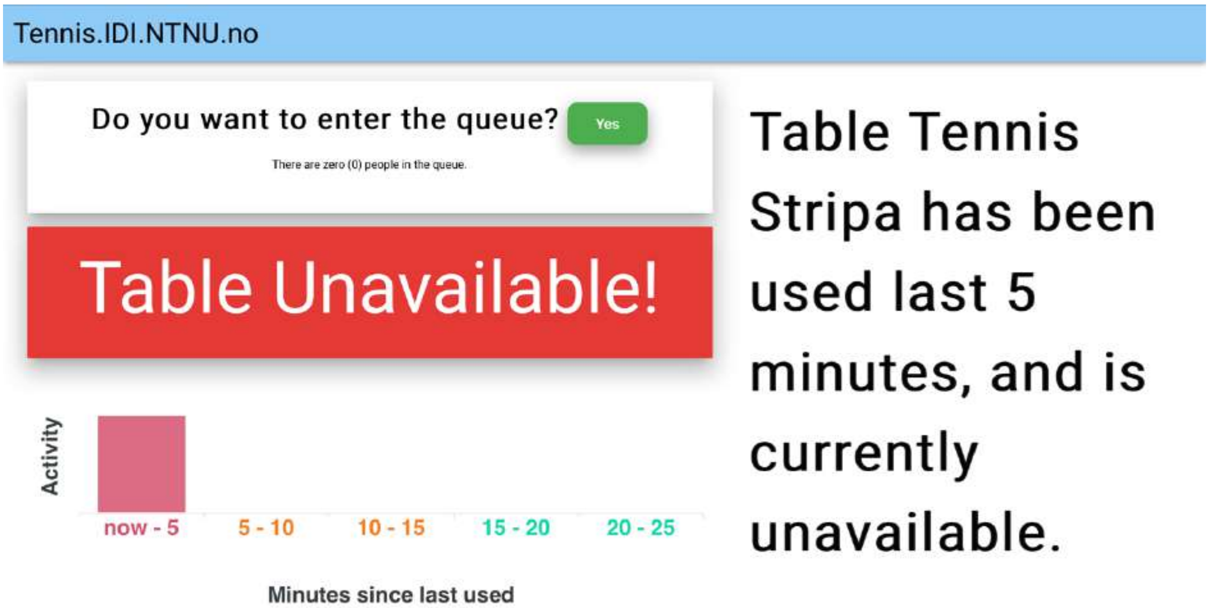


Figure 5.5.2: Updated user interface with a queue feature, green version

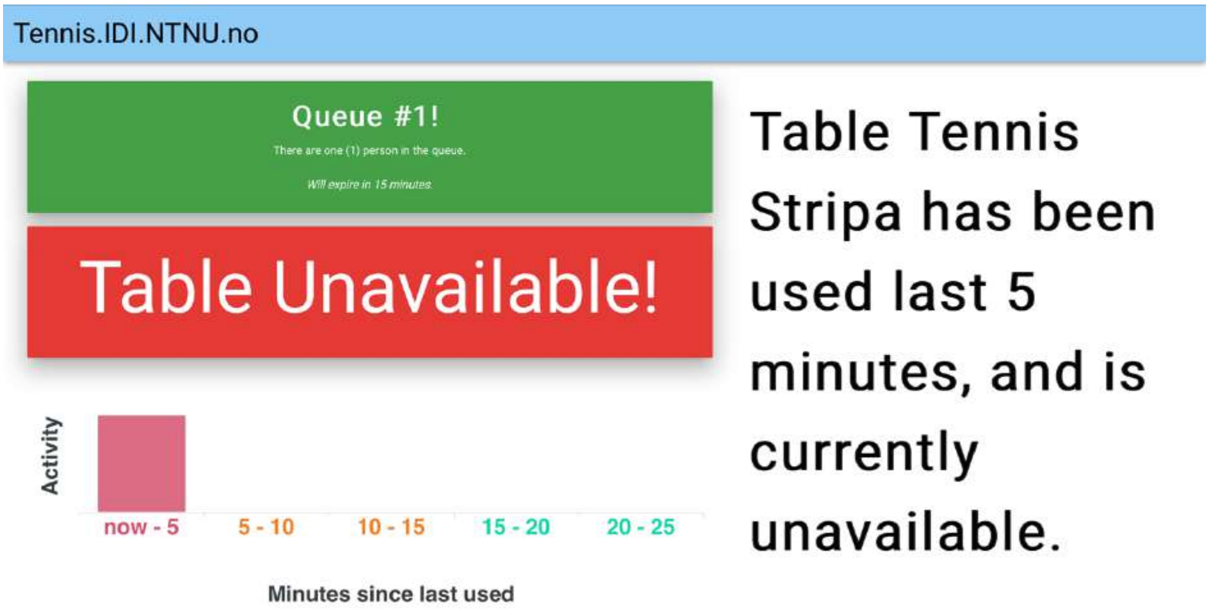


Figure 5.5.3: Updated user interface with a queue feature, green version

Without interference with normal operation of the tennis table, this study has focused on blending in the augmentation as an extra non-intrusive layer. Not having control over people playing tennis table without using the app, the queue position comes with a timer, so that it expires after 15 minutes if it is not renewed. A simple click updates the timer so that again 15 minutes remains. Having built the system to be non-intrusive and respect privacy, there is no method for interaction. This is solved by allowing for the queue position to expire. When 5 minutes remains, the text

"Will expire in 15 minutes."

gets expanded with an extra sentence

"Will expire in 5 minutes. Click here for additional time."

The box also change color to orange for the remaining 5 minutes, as illustrated in a figure below.

While a green button for pressing «Yes» after having been presented a question about entering the queue, making the entire box green might be misunderstood. So the study also featured an alternative, more neutral color. While one version featured green and the other featured blue, they both would change color to orange with 5 minutes remaining on the timer.

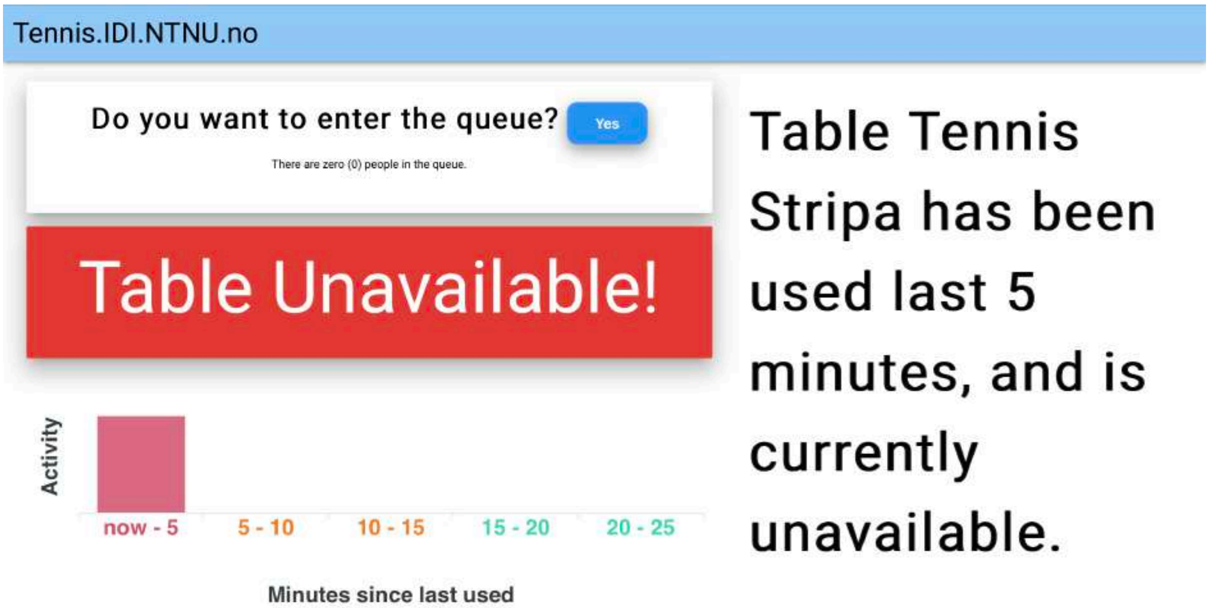


Figure 5.5.4: Updated user interface with a queue feature, blue version

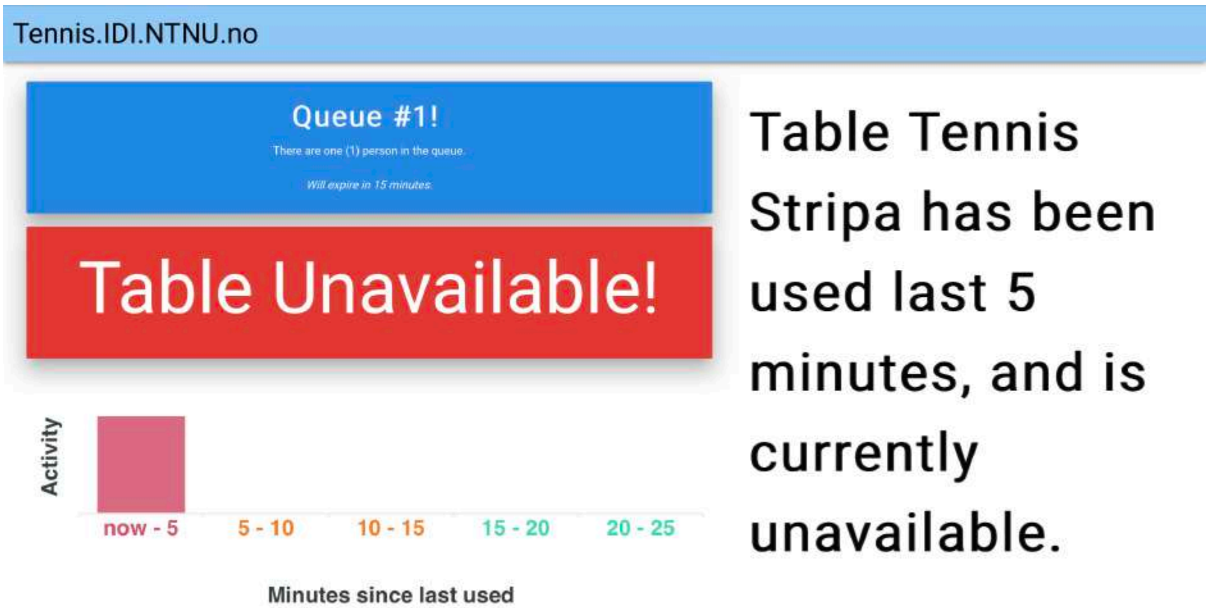


Figure 5.5.5: Updated user interface with a queue feature, blue version

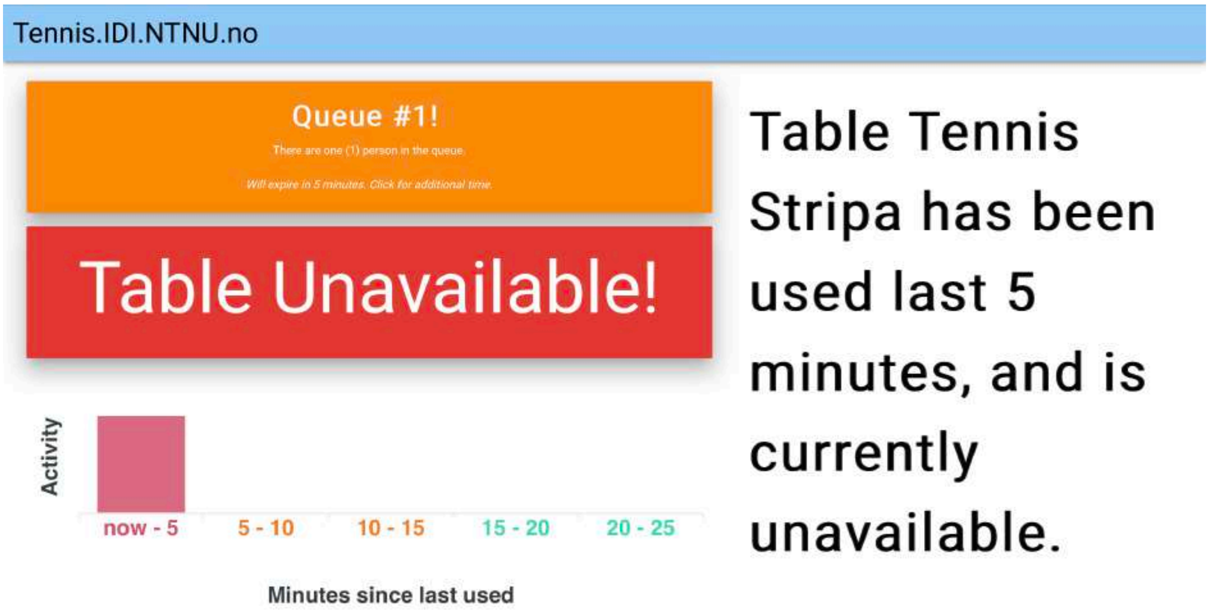


Figure 5.5.6: Updated user interface with a queue feature

One subject, somewhat impatient by nature, preferred green over blue, explaining that she found the color soothing and made her more confident that everything was in order. Another subject was more confused by the color, since the color green means good to go, so there the preference was on the blue version. Many subjects had serious problems noticing the new box that popped up on the screen with a white background. After some discussion we realized that these subjects have developed a blind spot to anything that resembles advertisements. One subject spent as much as two full minutes intensely looking at the screen before she was able to recognize that there was new information. Next iteration will therefore avoid white background, and rather show white text on an orange background. When users click Yes, the color then should change to blue. Orange works for attracting attention, and the change of background color serve as a confirmation. With only 5 minutes remaining on the timer, the background color will change to orange in an attempt to get attention from the user and inform about the possibility of extending time.

5.5.1. Eye-Tracking Heat Maps

The Tobii Eye Tracker system also has the ability to generate heat maps. Heat maps is an aggregation of all areas the subjects have looked at, showing areas that has attracted more attention as warmer.

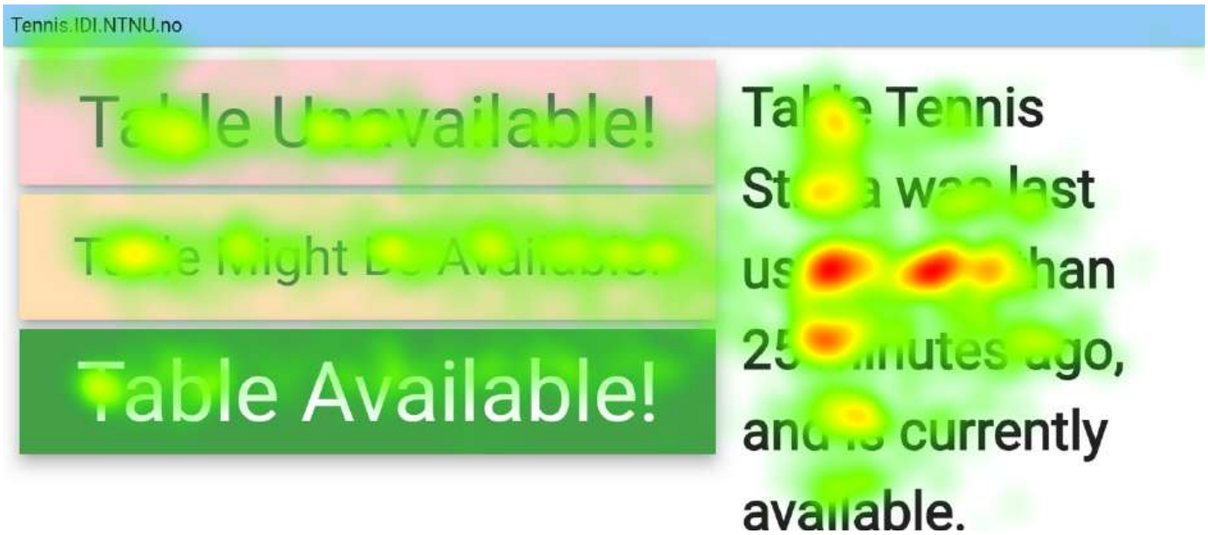


Figure 5.5.7: Heat map of all 8 subjects doing the traffic light user interface

A heat map of the traffic light user interface shows that subjects paid a lot of attention to the text on the right side, while attention to the three modes were more distributed between “Table Unavailable!”, “Table Might Be Available!” and “Table Available!”.

Figure 5.5.8: Heat map of all 8 subjects doing the graph user interface

While a heat map of the graph user interface shows that subjects paid most attention to the graph on the left side.

Figure 5.5.9: Heat map of one subject doing the queue user interface

Heat maps were also generated in round two of the Eye Tracking Usability Test, testing the implementation of a digital queue system with different colors of the queue banner. We see that most attention is directed to the information about queue position, total number of people in the queue and time remaining in the digital queue. The smaller font might also have contributed to more time being spent looking at a particular spot on the screen.

5.6. Research Questions

This study aimed to answer three research questions.

Research Question #1:

> **In what ways can table tennis be digitally augmented while preserving anonymity and privacy?**

Unlike most research focused on augmentation, which use state of the art technology like cameras and projectors, for tracking and visual feedback, this study was interested in ways that allowed for augmentation while preserving anonymity and the privacy of those playing table tennis. For answering research question #1, the study explored if a vibration sensor would be sensitive enough to detect vibration caused by a ping pong ball bouncing on top of a tennis table. This was confirmed using piezo contacts connected to an Arduino. The Arduino was replaced with an ESP32 for internet connectivity, and vibration sensors mounted on the tennis table were provided by El-Watch. Detecting vibration at the tennis table cannot be used for identification of a player's identity, and thus an augmentation method that is preserving anonymity and privacy.

Research Question #2:

How can digital augmentation improve the table tennis user experience?

Research Question #3:

How can digitally augmented table tennis increase availability awareness?

Research questions #2 and #3 focused on the improvement of the table tennis user experience through digital augmentation, and how digital augmentation can increase availability awareness. For many, especially during times of high demand, it is tiresome wanting to make an activity break with table tennis and repeatedly find that the table in unavailable after coordinating with friends to make the trip. When asking subjects when they are more likely to use the digital user interface, they all responded that they are more likely to use their mobile phone on campus when they are in close proximity, for instance after class or during a break. Clearly, the user experience is therefore improved through digital augmentation, allowing users improved availability awareness with the simple act of visiting a website. Scanning a QR code or visiting a link, allow for students to quickly learn about the availability of a tennis table nearby and should the table be unavailable, students can enter a queue with one touch. For students, the use of smart phones has become an integrated part of daily activities. With improved availability awareness through a web service, students can effortlessly check for availability on their phone within seconds. Instead of convincing friends to join on a trip to check if the tennis table is available, digital augmentation allow for a convincing argument when it is possible to tell your friends upfront that the tennis table is currently available.

6. DISCUSSION

In this chapter various aspects of the study are discussed and interpreted. Conclusions and recommendations for future work are presented in separate chapters. Following the User Centered Design approach makes planning and execution challenging, since it is impossible to plan the entire study. The study shapes and molds according to user requirements. It is feedback from users that determine if more iterations are needed, and if initial design solution is not sufficient to solve user requirements, then more design solutions need to be produced in order to reach a system that fulfill user requirements.

6.1. Results

Initial results of the study showed that an additional iteration was needed, in order to accommodate for design changes following a comparative investigation into what user interface subjects preferred, and the implementation of a queue system as users found that to be a better alternative to the implementation of a booking system. Vibration sensors were found to serve as a preferred method of tennis table augmentation, an anonymity and privacy preserving choice which has no visible cameras and cannot be used to identify who is playing. While a camera can be set up in a way that only allow for it to track a ping pong directly above the tennis table, more technical knowledge and understanding is needed by those playing to develop and accept this understand at a deep enough level. A more natural and intuitive association is that with CCTV (closed-circuit television), associating a camera with constant monitoring of public spaces. This association has been avoided by putting a vibration sensor underneath the tennis table, with the added benefit of not being visible to those wanting to play, and thus avoiding the act of inflicting uncertainty and fear in the casual player.

The study has answered research question #1 with the choice of a vibration sensor of augmenting data from the tennis table, and research questions #2 and #3 were extensively researched with observations, interviews, workshops, and eye-tracking studies. Availability awareness has been improved with a mobile friendly website that can be easily accessed with a link or a QR code. The website has a minimal use of frameworks that allow for fast loading. Initial prototype was done with React, but loading time was slow, so it was replaced with Flask and jQuery. Once loaded, it serves as a real-time application, which updates when underlying status of the tennis table changes. It is now possible to gain availability awareness on your mobile phone in matter of seconds, providing a user friendly experience in an application that the study has shown is an intuitive and easy to use interface. In addition to availability awareness, the application encourages use of the tennis table by entering a queue in the unfortunate event of the table being unavailable. Before entering the queue, the user will be able to see if there are others already in the queue, with real-time updates for what placement the user has in the queue. If the table has been available for more than 5 minutes, everything related to the queue system disappears, and the system no longer says that the table is unavailable.

An added bonus of doing a queue system is that the implementation is preserving anonymity and privacy. A booking system normally require the user to sign up and share personal information, so that the system can for instance send reminders in the form of an email or a text message. In order to give penalty for not showing up to a booking, the system also needs to collect identifiable information about the user. Booking is more formal, putting more demands on the users, forcing the user to make plans ahead in time. Booking can also serve as a point of annoyance because tables tennis is considered to be a casual activity. Allowing for booking more than 24 hours in advance would therefore not be natural. This perspective was shared by a subject during the interview after an eye-tracking session. Some users might find this to be a strange limitation, considering that other booking solutions that students are used to have a 72 hours limit. A queue system reinforces the casual nature of the game, with the intuitive understanding that a no-show in the queue just means that others get to advance faster.

6.2. Challenges

This study has been filled with challenges. The biggest challenge was to make the decision for what to actually do in the master thesis. Initial efforts went into building a Raspberry Pi box that was able to read both RFID and NFC cards. Student identification cards at NTNU actually comes with both, so a lot of effort went into the possibility of building an app that could read the NFC part of student cards and somehow bridge that with RFID that was more commonly used by other student associations. Other student groups would for instance require students to enter a number found at the back of the student card, which a script would be able to connect with the RFID number associated with the card. So that students just needed to scan their student cards when entering events, making purchases from the student association office kiosk, etc.

Before playing table tennis, both users would have to scan their student identification card, and the winner of the match got to scan their student card again, so that the system could know who played and who won. Somehow, the player would then also be able to see matched played, ranking, etc. in an app, by scanning the NFC part of the student card. Since the box could read both RFID and NFC, both could be read and associated with the same account.

While building the box was successful, continued efforts were deemed highly risky, since it could be a challenge collecting data with this approach, considering how the system is vastly different from what users are already used to. An alternative path of the master thesis emerged, since there was a need at NTNUi Tennis to track who showed up for practice. Normally 4 students could reserve a spot, so that typically at least 3 students show up. But if only two students have confirmed, and one person is a no-show, then that results in a bad experience for the student that has nobody to play with. During this period an observation was made about the frustration of always finding the tennis table occupied, which gave rise to the idea of digital augmentation of tennis tables, resulting in more work on the hardware side.

Having first built an Arduino device attached to piezo contacts for detecting vibrations, additional effort was made to connect the device to the internet by replacing the

Arduino with an ESP32. While tempted to optimize the ESP32 for minimal power usage, it was determined to be outside the scope of this thesis, and before a battery powered homemade sensor could be installed, it was decided to rather use vibration sensors provided by El-Watch. Those came with a gateway, sending vibration data in a JSON format. It was a major challenge to actually read the JSONs that was sent every two minutes, and at a higher frequency when people were playing table tennis.

Following the User Centered Design approach can be quite challenging, especially during a pandemic outbreak. While the prototype is working, allowing for on-sight field study, further considerations made us reach the conclusion that it would be better to collect data under more controlled circumstances. The User Centered Design approach presents many challenges, since it is impossible to know in advance what the user requirements will be and as such making it difficult to plan which activities that are necessary. Maintaining a tight time schedule with the User Centered Design approach can therefore a major challenge, and a major pandemic unlike anything we've seen the last 100 years adds to the list of challenges. Everything went into lockdown March 2020, creating significant challenges for data collection during spring of 2020. Fall 2020 was surprisingly normal in Trondheim, until a week before Christmas. The uncertainty of the whole situation made planning difficult since contingency plans also had to be made. There have been periods when the UX Lab has been closed, and other periods with strict restrictions which made it impossible for more than one person to use it. And every week a form had to filled with planned timeslots, making actual usage more complicated. Additional restrictions before and after Easter also caused challenges to the data collection process. With campus being closed for shorter and longer periods, analysis of usage data from the tennis table at campus has been a challenge, since there is nothing that can be considered normal anymore. With the slight exception of November 2020, directly after installing the vibration sensor at a public location on campus.

6.3. Methods

Initial work on this master thesis was exploratory, with a desire to support an active student life through the development of tools for students to engage in physical activity. Building technology and in the process trying to figure out how to use the technological innovation. Augmentation presented itself as a way forward, and this exploratory journey included gamification and ways that could help students engage in physical activity. Initial efforts eventually paid off, since it did result in the discovery of an actual need among students, confirmed by observations and interviews. Marking the adoption of the User Centered Design approach as a research methodology. Up till this point working methodology was more exploratory of nature, and somewhat chaotic in search for a “product-market fit”. Without millions in investor funding, it is difficult to “create” a market, so for a master thesis to become successful it is important to solve an actual need. The User Centered Design approach is great for identifying user requirements, producing design solutions, and evaluating if proposed design solutions meet system requirements. If not, the methodology dictates more iterations until user requirements are met.

A time consuming aspect of the User Centered Design approach is all the necessary interactions with users in both identifying what user requirements are, and then user evaluation to determine if these requirements have been met. While multiple low-fidelity paper prototypes were developed, more users could have been involved in this process, both in the development and evaluation of these prototypes. Workshops allowed for users to share their ideas and thoughts for how this vibration data could be used for building an application, and while the process did produce useful input to the process, many went far beyond building a minimum viable product in their proposal requiring a vibration sensor at every tennis table on campus. Which would cost a fortune using the technology provided by El-Watch, but more doable with ESP32 prototypes having internet connectivity instead of a gateway for each vibration sensor.

High-fidelity working prototypes that actually responds to usage of the tennis table opens up to the possibility of collecting data through other means that just for instance eye-tracking, like long-running field studies inviting students to scan a QR code and use the application deployed to production. Considerations with regards to the corona situation have resulted in a decision to not experiment with more data collection methods, and rather do two rounds of eye-tracking followed by interviews. While collected vibration data is preserving anonymity and privacy, it is hard to predict in these GDPR times what challenges might arise from a more public data collection effort. Some students might feel uncomfortable about any data being collected, and express this discomfort so strongly that the long-running field study rather become short lived. Even though permission has been granted for the collection of vibration data, such a permission can also be retracted if someone express discomfort for whatever reason. Collected data from the publicly accessible tennis table is therefore just being analyzed for descriptive statistics in this study.

When doing the comparative eye-tracking study, possible biases were minimized by starting with the “traffic light” user interface for one half of the group, and the graph user interface for the other half. Having understood the functions of one user interface, it gets easier to understand the other user interface. The graph interface was believed to be more advanced of the two, but it became clear that some subjects also found the “traffic light” interface to be confusing. In a normal traffic light there is only one color visible at any given time, with context and experience making it obvious what the color mean and what other colors that exist in the system. The “traffic light” user interface chose to make the non-active colors more “faded”, so that you could see that the light symbol also had two other alternatives. The moment subjects realized that it was supposed to symbolize a traffic light it became obvious, but there were subjects in the comparative study that needed some time to make that connection.

7. CONCLUSIONS

This master thesis set out to explore how table tennis could be digitally augmented, and how the user experience could be improved through enhanced awareness availability. User Centered Design approach was employed to discover user requirements, develop design prototypes, and evaluate results against system requirements. Based on feedback from users, user requirements have been updated resulting in improved prototypes through an iterative process. Table tennis has been augmented throughout history in many shapes and forms, like visualizations projected to the surface of a tennis table as a response to vibrations caused by a ping pong ball, remaking the table tennis experience to suit three players in remote locations using a camera and a projector, and also using augmentation to build a table tennis trainer. This study might be the one of the few that digitally augment table tennis in a manner which preserve anonymity and privacy. In order to answer the first research question, a vibration sensor was installed on a tennis table, digitally augmenting information derived from this sensor. Information is made accessible without the need to create an account, thus preserving anonymity and privacy. Before this study, the table tennis user experience was limited to a physical investigation of the table and necessary equipment. Since playing table tennis is a social experience, coordination with friends is necessary before the ability to initiate a playful and active break together. While friends might eagerly say yes upon information about the table being available with equipment like rackets and balls in good condition, they might be more hesitant with all these risks unresolved until actually going to the table to make an inspection. Through digital augmentation, students now have an improved table tennis user experience with increased availability awareness at their fingertips. Second and third research question have therefore also been answered. While Internet of Things is often mentioned in connection with the 4th industrial revolution, this study has shown that using Internet of Things to augment physical artifacts like tennis table, show also a great potential in the consumer market.

8. FUTURE WORK

During a regular semester demand for playing table tennis is moderate, with high probability for finding the tennis table available. As exam period approaches, regular classes come to an end and students have more free time during a regular day, so does demand for playing table tennis. It is a popular procrastination activity, and students also have a greater need for activity breaks from exam preparations when their schedule has fewer activities. Quickly you get a situation that some students play a lot, far more than they should. While other students that would occasionally play table tennis, just give up on finding the tennis table available during periods of high demand. Digital augmentation with a queue system allows for more students to play. Young and vigorous students are no longer able to play for hours, and a queue system allow access for more students to play. Another benefit is that increased availability awareness makes it easier for a group of friends to make the decision to play table tennis, since they no longer need to physically investigate the table to check it the tennis table is available. This hypothesis should be tested in a field study throughout an entire semester in future work, a semester without lockdown, digital classes, and digital exams.

Future work can also include more tennis tables, so that the user interface can be expanded with a map that give an overview of all tennis tables on campus for a quick understanding of which table the is currently available. When entering the map view, users can be asked to share location, so that users can see relative location of available tables to the user's current location. If a tennis table is unavailable, the user interface can recommend the nearest table that is available. A common problem with tennis tables is that ping pong balls disappear or get destroyed, making it impossible to play. Rackets can also break, needing a replacement before it is possible to resume playing. Currently there is no system for detecting such anomalies, but rich vibration data, including seasonal changes, makes it possible to send an email to those responsible for replacing equipment after prolonged periods of unusually low activity levels. Some students bring their own rackets and ping pong balls, which should be considered in such an analysis. Those who bring their own equipment often have more experience in playing table tennis, so that can be determined in analysis of vibration data. Historical vibration data can also be made accessible in the user interface through the use of an interactive JavaScript charts library. For instance, can all historical data points be made accessible through one chart, even when number of data points are in the millions. This is possible with asynchronous server loading, as more data is loaded when the user zoom in on specific dates.

With the current implementation, users can identify that the table is available, but are required to find friends to play with on their own. Future work can include the possibility of sending a notification to students nearby, who are not currently occupied with classroom lectures. This work can be combined with expansion of the user interface that allow users to create an account and register scores, making it possible to generate a ranking. So, when a user broadcast a desire to play with others nearby, this broadcast can be narrowed down to those who have a similar ranking. Instead of manually entering the score in an expanded form of the user interface, future work can allow for students to scan their student identification card for registering both players and inviting the winner to scan the student card a second time. Such a system would work without the need to register in advance. A non-hardware design solution would also allow for scores to be entered into an expanded user interface, without requiring students to register in advance, through the use of phone numbers. That way, one of the players needs to enter the phone number of both players and the score, for the match to be considered in an updated ranking. Similar to how Vipps works for transferring money between phones. When the student eventually register for an account, the student would be required to register with a phone number, making prior matches visible in the account history along with ranking placement.

With a system for registering scores, future work can also include something called a box league. A low-threshold tournament system that assign players to a group of 5 with monthly updates, so that players are required to play 4 matches during a month. Top two players during the month progress to a “box” above, and bottom two players are downgraded to a “box” below. The fifth player remains in the same “box”, but get four new opponents the following month. For additional challenges, the box league system can become more intelligent by allowing new players in the box league to faster reach their correct ranking placement, in accordance with more advanced analysis of vibration data and point differences in scores.

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APPENDICES

A. NSD Approvals and Interview Guides

Three applications have been sent to Norwegian centre for research data (NSD). First application was to gather permission to do semi-structured interviews for understanding and specify the user context, and to specify user requirements, in accordance with the User Centered Design approach.

Second application was to gather permission to do the first round of user testing with Eye-Tracking and interviews on eight subjects in order to test design solutions and evaluate if they meet user requirements.

Third application was to gather permission to do the second round of user testing with Eye-Tracking and interviews. Before arriving at a service that meet user requirements, feedback was gathered from users during the evaluation against the user requirements step. A desire for a digital queue system was expressed. Design solutions to meet user requirements were therefore updated in an iteration, and user tested on five subjects with Eye-Tracking and interviews.

A.1. Semi-structured interviews

Intervjuguide: (Semi-strukturert, åpne spørsmål, 15-20 minutter)

- Navn:
- Alder:
- Studie:
- Antall år i høyere utdanning:
- Kommer fra:
- Hvilken form for fysisk aktivitet gjør du?

- Hvilke idretter har du drevet med tidligere?
- Hvorfor spiller du bordtennis?
- Liker du å spille bordtennis?
    - Dersom ja/nei:

      Trening? Tidsfordriv? Bli bedre? Sosialt?
- Hvilken følelser får du av å spille bordtennis?
- Hvor ofte spiller du bordtennis?
- Har du perioder hvor du spiller mer eller mindre bordtennis?
- Har du hatt erfaringer med dårlig utstyr (racketer, bordtennis ball, nett, etc.)?
    - *Dersom ja:*

      Hva følelse får du av å finne et bordtennisbord uten utstyr som fungerer?
- Opplever du det som utfordrende å finne passende spillepartnere?
    - *Dersom ja/nei: Hvorfor?*
- Hva tenker du om muligheten for at resultater blir registrert etter hver kamp?
- Hva kan bli gjort for å forbedre opplevelsen av å spille bordtennis?
    - Legge til eller fjerne noe?
    - Gjøre bordtennis reservasjon mulig?
    - Vil informasjon om bordtennisbordets ledighet være av interesse?

Interview guide: (Semi-structured, open questions, 15-20 minutes)

- Name:
- Age:
- Study:
- Number of years in higher education:
- Birthplace:
- What form of physical activity do you do?
- Which sports have you done previously?
- Why do you play table tennis?
- Do you like playing table tennis?
    - If yes/no:
      Exercise? Passing time? Improve? Social interaction?
- How does table tennis make you feel?
- How often do you play table tennis?
- Do you have periods where you play more or less table tennis?
- Have you had experience with bad equipment (rackets, table tennis ball, net, etc.)?
    - *If yes:*
      How does it make you feel finding a table tennis table without working equipment?
- Do you find it challenging to find a suitable playing partner?
    - *If yes/no: Why? How?*
- How do you feel about scores being recorded after matches?
- What can be done to improve the experience of playing table tennis?

- Add or remove something?
- Would information about the availability of table tennis tables be of interest?
- Make table tennis reservations possible?

A.1. Statement of consent

Vil du delta i forskningsprosjektet

"Digital augmentasjon av bordtennis brukeropplevelsen"?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å avklare preferanse ved spilling av bordtennis og eventuelt avdekket hvordan teknologi kan gjøre brukeropplevelsen bedre. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Masteroppgave med fokus på bordtennis og teknologi. I forstudiet er formålet å forklare preferanser. Oppgaven vil undersøke om teknologi kan gjøre et bidrag til brukeropplevelsen.

Hvem er ansvarlig for forskningsprosjektet?
NTNU er ansvarlig for prosjektet.

Hva innebærer det for deg å delta?
Hvis du velger å delta i prosjektet, innebærer det at du svarer på noen spørsmål relatert til bordtennis. Det vil ta deg ca. 15-20 minutter. Jeg tar lydopptak fra intervjuet i tilfelle det blir aktuelt å bruke sitat.

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykke tilbake uten å oppgi noen grunn. Alle opplysninger om deg vil da bli anonymisert. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket. Deltakerne vil ikke kunne gjenkjennes i masteroppgaven.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Prosjektet skal etter planen avsluttes 1. juni 2021. All innhentet informasjon anonymiseres og lydopptak slettes innen utgangen av prosjektet.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg,
- å få rettet personopplysninger om deg,
- få slettet personopplysninger om deg,
- få utlevert en kopi av dine personopplysninger (dataportabilitet), og
- å sende klage til personvernombudet eller Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra NTNU har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- Masterstudent Lars Føleide <larsfole@stud.ntnu.no>
- NTNU ved veileder George Adrian Stoica <stoica@ntnu.no>
- Vårt personvernombud: Thomas Helgesen <thomas.helgesen@ntnu.no>
- NSD – Norsk senter for forskningsdata AS, på epost (personverntjenester@nsd.no) eller telefon: 55 58 21 17.

Med vennlig hilsen

Prosjektansvarlig
(veileder)

Lars Føleide
(student)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *Digital augmentasjon av bordtennis brukeropplevelsen*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

☐ å delta i et intervju

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet, ca. juni 2021

(Signert av prosjektdeltaker, dato)

A.1. NSD Approval

18.03.2020 15:21
Det innsendte meldeskjemaet med referansekode 699526 er nå vurdert av NSD.

Følgende vurdering er gitt:

Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet med vedlegg den 18.03.2020, samt i meldingsdialogen mellom innmelder og NSD. Behandlingen kan starte.

MELD VESENTLIGE ENDRINGER
Dersom det skjer vesentlige endringer i behandlingen av personopplysninger, kan det være nødvendig å melde dette til NSD ved å oppdatere meldeskjemaet. Før du melder inn en endring, oppfordrer vi deg til å lese om hvilke type endringer det er nødvendig å melde:

nsd.no/personvernombud/meld_prosjekt/meld_endringer.html

Du må vente på svar fra NSD før endringen gjennomføres.

TYPE OPPLYSNINGER OG VARIGHET
Prosjektet vil behandle alminnelige kategorier av personopplysninger frem til 01.06.2021.

LOVLIG GRUNNLAG
Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 og 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse som kan dokumenteres, og som den registrerte kan trekke tilbake. Lovlig grunnlag for behandlingen vil dermed være den registrertes samtykke, jf. personvernforordningen art. 6 nr. 1 bokstav a.

PERSONVERNPRINSIPPER

NSD vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen om:

- lovlighet, rettferdighet og åpenhet (art. 5.1 a), ved at de registrerte får tilfredsstillende informasjon om og samtykker til behandlingen
- formålsbegrensning (art. 5.1 b), ved at personopplysninger samles inn for spesifikke, uttrykkelig angitte og berettigede formål, og ikke behandles til nye, uforenlige formål
- dataminimering (art. 5.1 c), ved at det kun behandles opplysninger som er adekvate, relevante og nødvendige for formålet med prosjektet
- lagringsbegrensning (art. 5.1 e), ved at personopplysningene ikke lagres lengre enn nødvendig for å oppfylle formålet

DE REGISTRERTES RETTIGHETER

Så lenge de registrerte kan identifiseres i datamaterialet vil de ha følgende rettigheter: åpenhet (art. 12), informasjon (art. 13), innsyn (art. 15), retting (art. 16), sletting (art. 17), begrensning (art. 18), underretning (art. 19), dataportabilitet (art. 20).

NSD vurderer at informasjonen om behandlingen som de registrerte vil motta oppfyller lovens krav til form og innhold, jf. art. 12.1 og art. 13.

Vi minner om at hvis en registrert tar kontakt om sine rettigheter, har behandlingsansvarlig institusjon plikt til å svare innen en måned.

FØLG DIN INSTITUSJONS RETNINGSLINJER

NSD legger til grunn at behandlingen oppfyller kravene i personvernforordningen om riktighet (art. 5.1 d), integritet og konfidensialitet (art. 5.1. f) og sikkerhet (art. 32).

For å forsikre dere om at kravene oppfylles, må dere følge interne retningslinjer og/eller rådføre dere med behandlingsansvarlig institusjon.

OPPFØLGING AV PROSJEKTET

NSD vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Lykke til med prosjektet!

Tlf. Personverntjenester: 55 58 21 17 (tast 1)

A.2. Eye-Tracking #1 including interviews

Eye-tracking intervjuguide: (Semi-strukturert, åpne spørsmål, 15-20 minutter)

- Kan du beskrive opplevelsen av de to ulike grensesnittene?
- Føler du at trafikklys-grensesnittet gav nok informasjon, eller skulle du ønske noe mer detaljert?
- Hvilket design foretrekker du av A og B? Og hvorfor?
- A: Er det ønskelig med detaljert informasjon dersom bordet kanskje er ledig?
- B: Er informasjonen presentert i grafen forståelig?
- Vise utskrift av mobilgrensesnitt: Hva tenker du om forskjellen på grensesnittet ved bruk av mobil versus laptop?
- Er det mer sannsynlig at du vil bruke grensesnittet med en mobil eller en laptop?
- Hvilket design opplever du som mest intuitivt?
- Hvor er det mest sannsynlig at du vil bruke grensesnittet? På lesesalen, grupperom, på bussen, i forelesning, hjemme, etc.?
- Hva slags informasjon skulle du ønske en slik side inneholdt?
- Har du noen forslag til forbedringer?

- Tenk deg at bordet er opptatt, men at det er mulighet for å reservere bordet frem i tid. Hva tenker du om en slik booking-funksjon?

- Hva forventer du av en slik booking-funksjon med tanke på funksjonalitet, og hvordan bør den se ut?

- Hva tenker du om en kart-løsning som viser oversikt over ulike bordtennisbord?

- Hva forventer du av en kart-løsning med tanke på funksjonalitet, og hvordan bør den se ut?

- Er det noe annet en bruk av bordtennisbord du gjerne skulle ha sett tilgjengelig i grensesnittet?

Eye-tracking interview guide: (Semi-structured, open questions, 15-20 minutes)

- Can you describe your experience of the two interfaces?

- Do you feel that the traffic light interface gave enough information, or do you wish for something more detailed?

- What design do you prefer, A or B? And why?

- A: Would you desire more detailed information in the case of the table potentially being available?

- B: Is information in the graph presented in an understandable manner?

- Show printed version of mobile interface: What do you think of the difference between laptop and mobile interface?

- Is it more likely that you will use the interface with a mobile or a laptop?

- What design did you find more intuitive?

- Where is it that you are more likely to use the interface? At the study hall, group rooms, at the bus, during lectures, at home, etc.?
- What type of information do you wish a service like this would contain?

- Do you have any suggestions for improvements?

- Imagine that the table is taken, but that it is possible to reserve the table for future use. What are your thoughts about implementing a booking-feature?

- What would you expect from a booking-feature with regards to functionality, and how should it look like?

- What do you think about the implementation of a map-solution that shows an overview of different table tennis tables?

- What would you expect from a map-solution with regards to functionality, and how should it look like?

- Is there anything than table tennis tables you would like to see the accessibility of in this user interface?

A.2. Statement of consent

Vil du delta i forskningsprosjektet

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Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å avdekke preferanse relatert til brukeropplevelsen for å se når et bordtennisbord er i bruk eller ikke. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Masteroppgave med fokus på bordtennis og teknologi. I studiet er formålet å avklare preferanser relatert til brukergrensesnittet. Oppgaven vil undersøke om teknologi kan gjøre et bidrag til brukeropplevelsen.

Hvem er ansvarlig for forskningsprosjektet?
NTNU er ansvarlig for prosjektet.

Hva innebærer det for deg å delta?
Hvis du velger å delta i prosjektet, innebærer det at du gjennomfører en brukertest og svarer på noen spørsmål relatert til brukergrensesnittet. Det vil ta opp mot en time, sannsynligvis mindre. Det blir gjort lydopptak fra intervjuet i tilfelle det blir aktuelt å bruke sitat. Selve brukertesten bruker eye-tracking teknologi for å registrere hvor du ser, som er supplert med opptak fra et webkamera.

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykke tilbake uten å oppgi noen grunn. Alle opplysninger om deg vil da bli anonymisert. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

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Prosjektet skal etter planen avsluttes innen utgangen av 2021. All innhentet informasjon anonymiseres og lydopptak slettes innen utgangen av prosjektet.

Dine rettigheter
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- innsyn i hvilke personopplysninger som er registrert om deg,
- å få rettet personopplysninger om deg,
- få slettet personopplysninger om deg,
- få utlevert en kopi av dine personopplysninger (dataportabilitet), og
- å sende klage til personvernombudet eller Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra NTNU har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- Masterstudent Lars Føleide <larsfole@stud.ntnu.no>
- NTNU ved veileder George Adrian Stoica <stoica@ntnu.no>
- Vårt personvernombud: Thomas Helgesen <thomas.helgesen@ntnu.no>
- NSD – Norsk senter for forskningsdata AS, på epost (personverntjenester@nsd.no) eller telefon: 55 58 21 17.

Med vennlig hilsen

Adrian Stoica
Prosjektansvarlig
(veileder)

Lars Føleide
Lars Føleide
(student)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *Digital augmentasjon av bordtennis brukeropplevelsen*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

☐ å delta i en brukertest, med tilhørende intervju

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet, ved utgangen av 2021

(Signert av prosjektdeltaker, dato)

A.2. NSD Approval

21.01.2021 10:00
Behandlingen av personopplysninger er vurdert av NSD. Vurderingen er:

NSD har vurdert endringen registrert 16.12.2020.

Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet med vedlegg den 21.01.2021. Behandlingen kan fortsette.

Vi har registrert 31.12.2021 som ny sluttdato for behandling av personopplysninger.

I tilfelle det skulle bli aktuelt med ytterligere utvidelse av den opprinnelige sluttdato (01.06.2021), må vi vurdere hvorvidt det skal gis ny informasjon til utvalget.

Det er lagt til et nytt utvalg i prosjektet: Utvalg 2, «Studenter og personer i 20-årene bosatt i Trondheim, invitert til UX Lab (User Experience Lab) ved NTNU for å delta på et Eye-Tracking studie».

LOVLIG GRUNNLAG – utvalg 2
Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 og 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse som kan dokumenteres, og som den registrerte kan trekke tilbake. Lovlig grunnlag for behandlingen vil dermed være den registrertes samtykke, jf. personvernforordningen art. 6 nr. 1 bokstav a.

DE REGISTRERTES RETTIGHETER – utvalg 2
Så lenge de registrerte kan identifiseres i datamaterialet vil de ha følgende rettigheter: åpenhet (art. 12), informasjon (art. 13), innsyn (art. 15), retting (art. 16), sletting (art. 17), begrensning (art. 18), underretning (art. 19), dataportabilitet (art. 20).

NSD vurderer at informasjonen som de registrerte vil motta oppfyller lovens krav til form og innhold, jf. art. 12.1 og art. 13.

Vi minner om at hvis en registrert tar kontakt om sine rettigheter, har behandlingsansvarlig institusjon plikt til å svare innen en måned.

OPPFØLGING AV PROSJEKTET
NSD vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Lykke til videre med prosjektet!

Kontaktperson hos NSD: Marita Ådnanes Helleland
Tlf. Personverntjenester: 55 58 21 17 (tast 1)

A.3. Eye-Tracking #2 including interviews

Eye-tracking intervjuguide kø-system:
(Semi-strukturert, åpne spørsmål, 15-20 minutter)

- Hvilken farge likte du best i de to grensesnittene?
- Føler du at grensesnittet gav nok informasjon, eller skulle du ønske noe mer detaljert?
- Er informasjonen presentert i grafen forståelig?
- Vise utskrift av mobilgrensesnitt: Hva tenker du om forskjellen på grensesnittet ved bruk av mobil versus laptop?
- Er det mer sannsynlig at du vil bruke grensesnittet med en mobil eller en laptop?
- Opplever du designet som intuitivt?
- Hvor er det mest sannsynlig at du vil bruke grensesnittet? På lesesalen, grupperom, på bussen, i forelesning, hjemme, etc.?
- Hva slags informasjon skulle du ønske en slik side inneholdt?
- Hvordan var opplevelsen av å forstå at det var mulig å melde seg opp i en kø?
- Hvordan var opplevelsen å melde seg på køen?
- Hva tenker du om at posisjonen i køen har en tidsbegrensning?

- Var det enkelt å forstå at du kunne fornye gjenværende tid?

- Har du noen forslag til forbedringer?

- Hva tenker du om en kart-løsning som viser oversikt over ulike bordtennisbord?

- Hva forventer du av en kart-løsning med tanke på funksjonalitet, og hvordan bør den se ut?

- Er det noe annet en bruk av bordtennisbord du gjerne skulle ha sett tilgjengelig i grensesnittet?

Eye-tracking interview guide queue-system:
(Semi-structured, open questions, 15-20 minutes)

- Which color did you prefer in the two interfaces?
- Do you feel that the interface gave you enough information, or do you wish for something more detailed?
- Is information in the graph presented in an understandable manner?
- Show printed version of mobile interface: What do you think of the difference between laptop and mobile interface?
- Is it more likely that you will use the interface with a mobile or a laptop?
- Do you experience the design as intuitive?
- Where is it that you are more likely to use the interface? At the study hall, group rooms, at the bus, during lectures, at home, etc.?
- What type of information do you wish a service like this would contain?
- How was the experience of understanding that it is possible to sign up for a queue?
- How was the experience of signing up to the queue?
- What are your thoughts about your position in the queue being limited in time?
- Was is easy to understand that you easily could renew remaining time?

- Do you have any suggestions for improvements?
- What do you think about the implementation of a map-solution that shows an overview of different table tennis tables?
- What would you expect from a map-solution with regards to functionality, and how should it look like?
- Is there anything than table tennis tables you would like to see the accessibility of in this user interface?

A.3. Statement of consent

Vil du delta i forskningsprosjektet

"Digital augmentasjon av bordtennis brukeropplevelsen"?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å avdekke preferanse relatert til brukeropplevelsen for å se når et bordtennisbord er i bruk eller ikke. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Masteroppgave med fokus på bordtennis og teknologi. I studiet er formålet å avklare preferanser relatert til brukergrensesnittet. Oppgaven vil undersøke om teknologi kan gjøre et bidrag til brukeropplevelsen.

Hvem er ansvarlig for forskningsprosjektet?
NTNU er ansvarlig for prosjektet.

Hva innebærer det for deg å delta?
Hvis du velger å delta i prosjektet, innebærer det at du gjennomfører en brukertest og svarer på noen spørsmål relatert til brukergrensesnittet. Det vil ta opp mot en time, sannsynligvis mindre. Det blir gjort lydopptak fra intervjuet i tilfelle det blir aktuelt å bruke sitat. Selve brukertesten bruker eye-tracking teknologi for å registrere hvor du ser, som er supplert med opptak fra et webkamera.

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykke tilbake uten å oppgi noen grunn. Alle opplysninger om deg vil da bli anonymisert. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket. Deltakerne vil ikke kunne gjenkjennes i masteroppgaven.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Prosjektet skal etter planen avsluttes innen utgangen av 2021. All innhentet informasjon anonymiseres og lydopptak slettes innen utgangen av prosjektet.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg,
- å få rettet personopplysninger om deg,
- få slettet personopplysninger om deg,
- få utlevert en kopi av dine personopplysninger (dataportabilitet), og
- å sende klage til personvernombudet eller Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra NTNU har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- Masterstudent Lars Føleide <larsfole@stud.ntnu.no>
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Med vennlig hilsen

Adrian Stoica
Prosjektansvarlig
(veileder)

Lars Føleide
Lars Føleide
(student)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *Digital augmentasjon av bordtennis brukeropplevelsen*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

☐ å delta i en brukertest, med tilhørende intervju

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet, ved utgangen av 2021

(Signert av prosjektdeltaker, dato)

A.3. NSD Approval

23.08.2021 10:48
Behandlingen av personopplysninger er vurdert av NSD. Vurderingen er:

NSD har vurdert endringen registrert 20.08.2021.

Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet med vedlegg den 23.08.2021. Behandlingen kan fortsette.

Det er lagt til et nytt utvalg i prosjektet: Utvalg 3.

LOVLIG GRUNNLAG – utvalg 3
Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 og 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse som kan dokumenteres, og som den registrerte kan trekke tilbake. Lovlig grunnlag for behandlingen vil dermed være den registrertes samtykke, jf. personvernforordningen art. 6 nr. 1 bokstav a.

DE REGISTRERTES RETTIGHETER – utvalg 3
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OPPFØLGING AV PROSJEKTET

NSD vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Kontaktperson hos NSD: Marita Ådnanes Helleland
Lykke til videre med prosjektet!

B. Timeline full-size

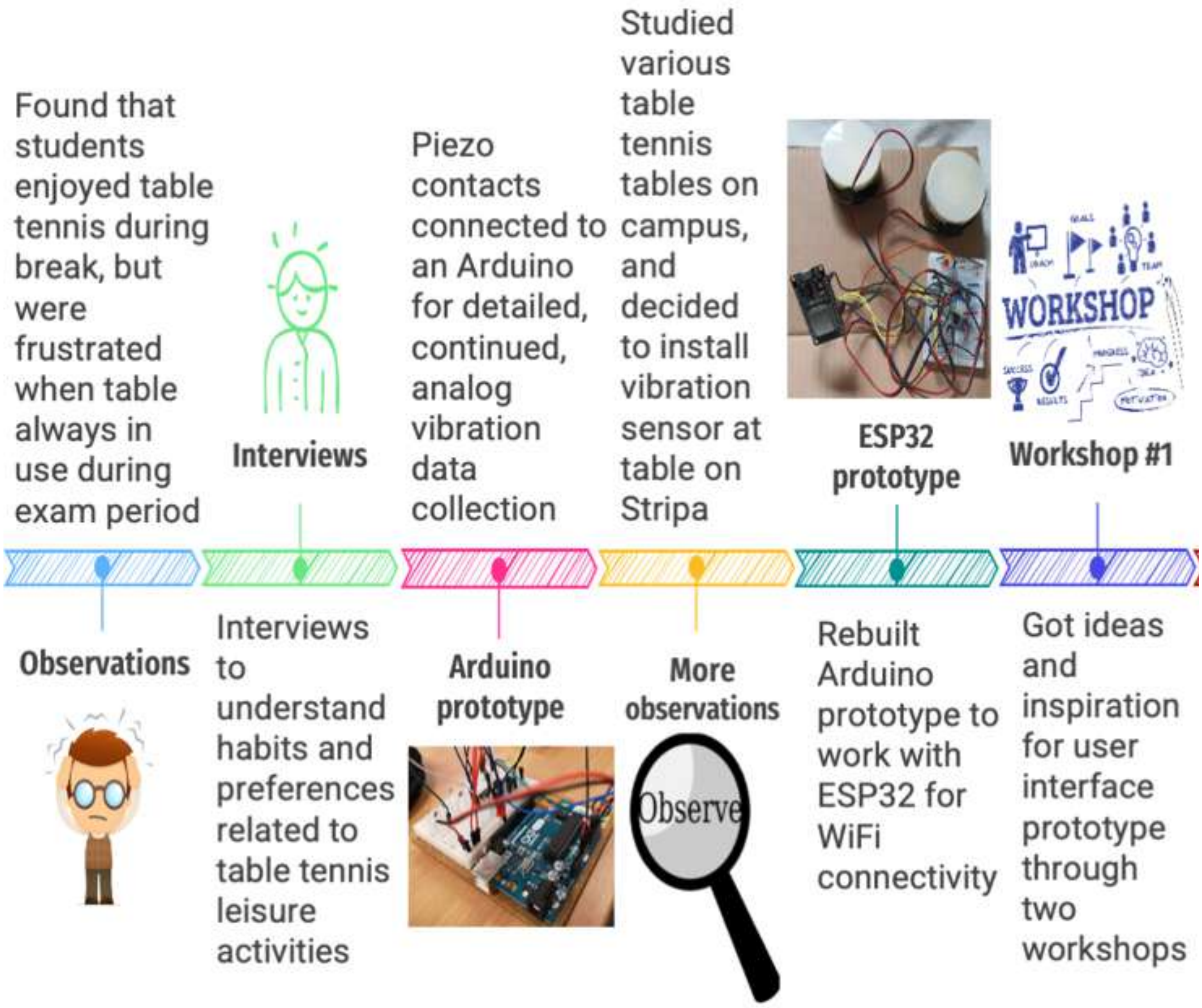

Figure B.1a: Timeline infographics of various data collection

(Photo credits: © artenot, © trueffelpix, © The EyeTribe, © Slidesgo)

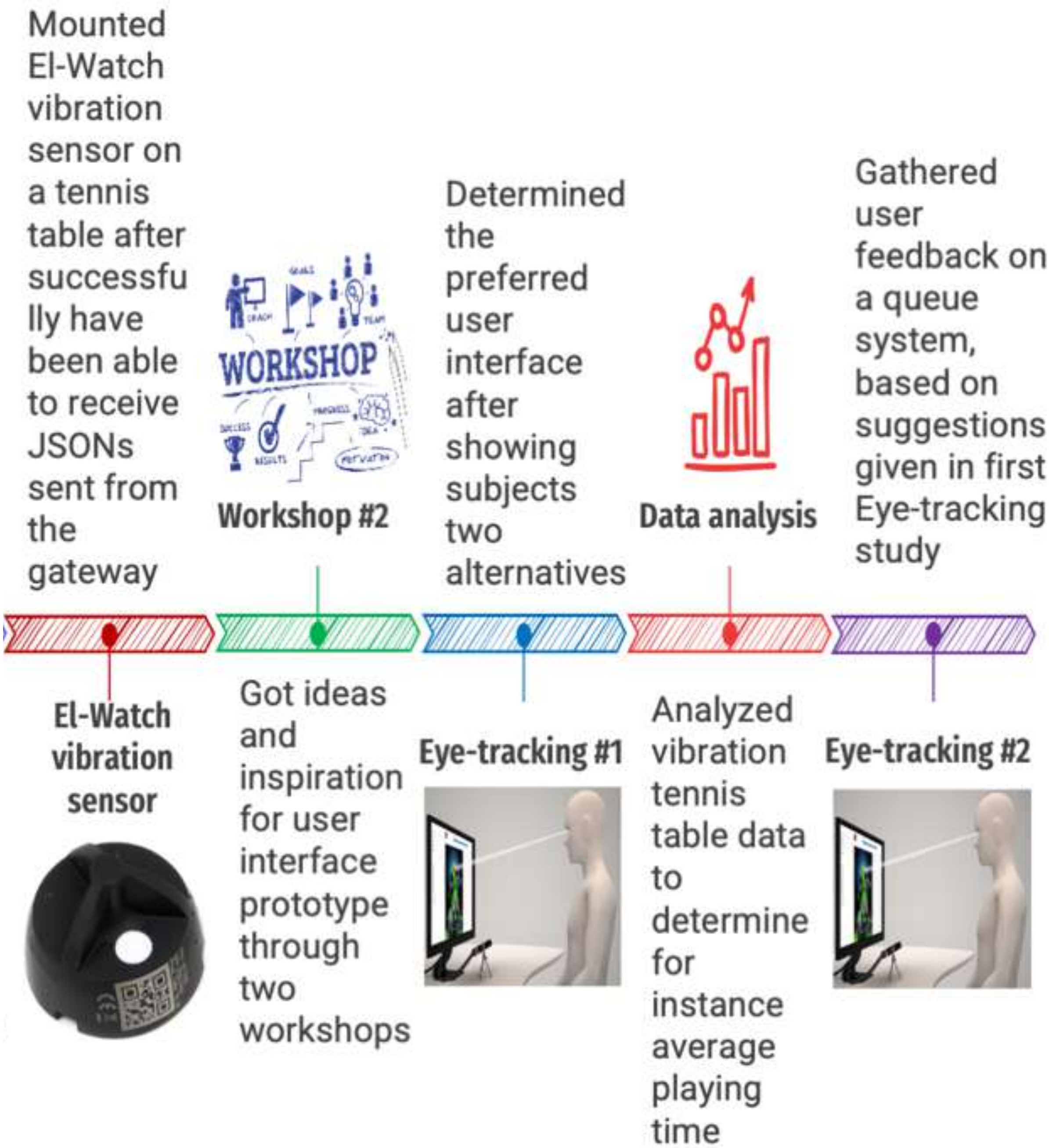

Figure B.1b: Timeline infographics of various data collection

(Photo credits: © artenot, © trueffelpix, © The EyeTribe, © Slidesgo)

C. Prototype schematics

Breadboard for the setup of two piezo contact sensors connected to an Arduino is shown below.

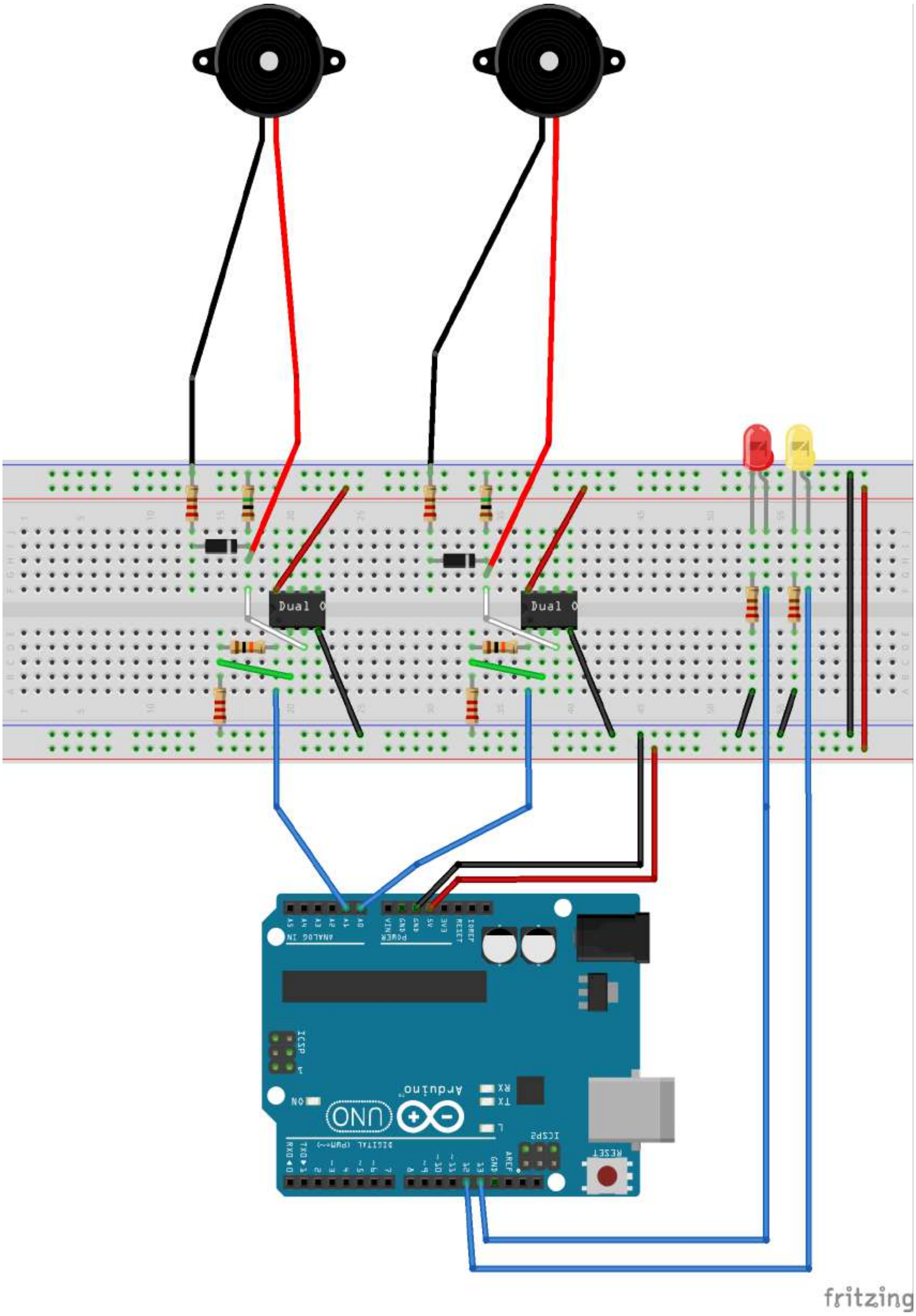

Figure C.1: Two piezo contact sensors connected to the Arduino Uno

Schematics for the setup of two piezo contact sensors connected to the Arduino Uno is shown below.

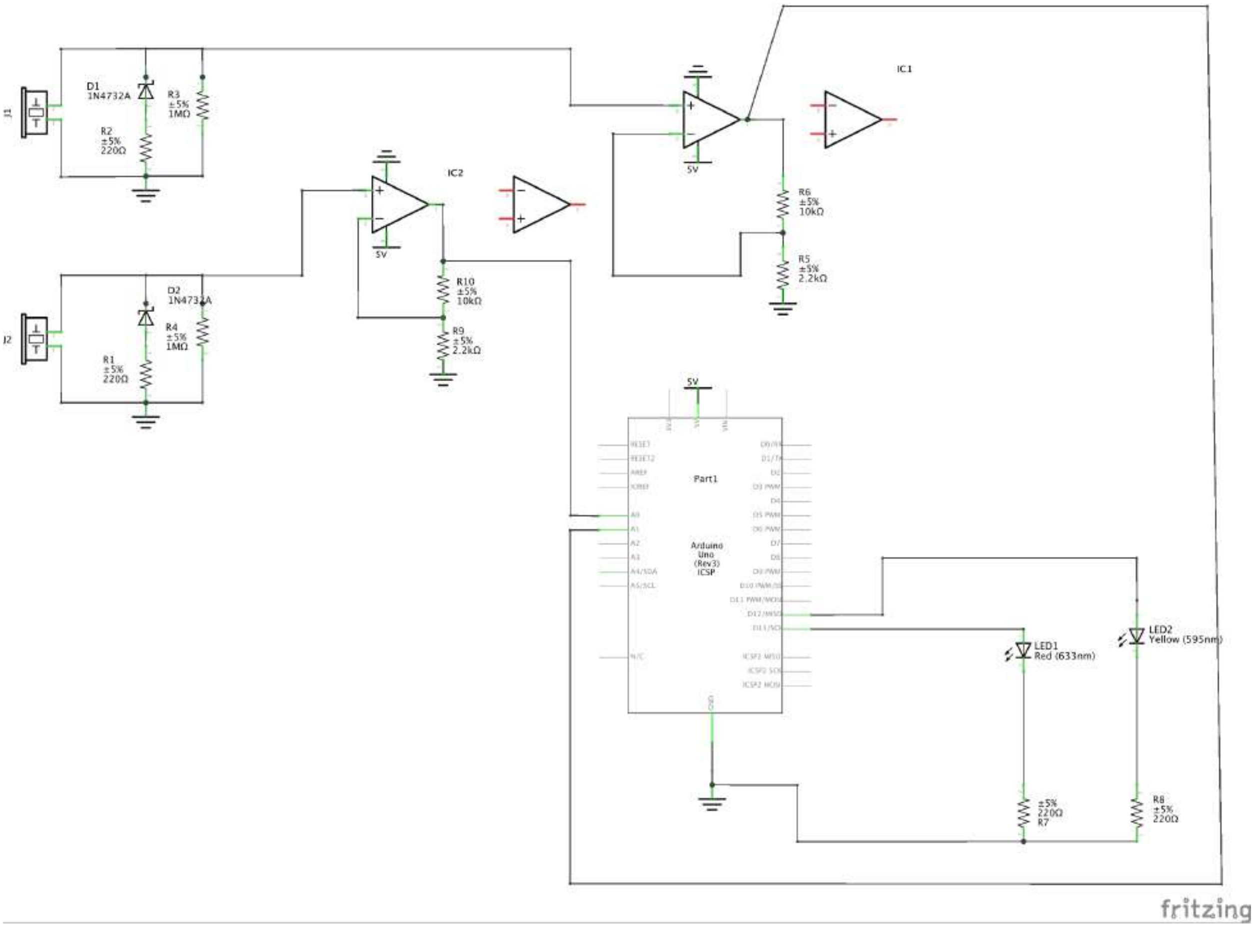

Figure C.2: Two piezo contact sensors connected to the Arduino Uno

Lars Føleide

Digitally Augmented Table Tennis User Experience

NTNU
Norwegian University of
Science and Technology