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Visualizing Time through Location Based Habits and Routines

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ABSTRACT

Mobile devices have become a massively prevalent part of everyday life, as their capabilities and functionality have expanded into new domains. One form factor that has attracted recent renewed interest is the smartwatch. This paper looks at how devices can be used to track the time, and in particular how we can invent new visualisations for timekeeping. It draws on different psychological theories of time to sketch out six new time visualisations, drawing on both old and new timekeeping devices as inspiration. These visualisations address *linear* time visualisations and *cyclical* time visualisations. The designs are contrasted with each other, with a final design selected and prototyped on the Apple Watch. The prototype is briefly evaluated through a 48 hour user test with one user. The design is then reiterated upon based on the feedback from this user test.

SAMMANFATTNING

Mobila enheter har blivit en allt större del av våra vardagliga liv i samma takt som deras kapacitet och funktionalitet har ökat och spridit sig till nya områden. Ett av dessa områden som nyligen fått ett nyfunnet intresse är smarta klockor. Den här uppsatsen tittar på hur mobila enheter och framför allt smarta klockor kan användas för att hålla reda på tiden. Den undersöker framför allt på hur vi kan ta fram nya sätt att visualisera tid. Arbetet bygger på olika psykologiska teorier om tid för att skissa sex stycken olika tidsvisualiseringar, de olika visualiseringarna använder också historiska tidmätningsinstrument som inspiration. Dessa visualiseringar bygger också på ett framtaget koncept om att tid kan ses som *konstant* eller *cyklisk*. Designförslagen jämförs sedan med varandra och en slutgiltig design väljs ut. En prototyp för Apple Watch skapas, baserat på den slutgiltiga designen. Prototypen utvärderas genom att en användare bär klockan under 48 timmar. Därefter förbättras och förändras designen baserat på återkopplingen från testet.

Visualizing Time through Location Based Habits and Routines

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ABSTRACT
Mobile devices have become a massively prevalent part of everyday life, as their capabilities and functionality have expanded into new domains. One form factor that has attracted recent renewed interest is the smartwatch. This paper looks at how devices can be used to track the time, and in particular how we can invent new visualisations for timekeeping. It draws on different psychological theories of time to sketch out six new time visualisations, drawing on both old and new timekeeping devices as inspiration. These visualisations address *constant* time visualisations and *cyclical* time visualisations. The designs are contrasted with each other, with a final design selected and prototyped on the Apple Watch. The prototype is briefly evaluated through a 48 hour user test with one user. The design is then reiterated upon based on the feedback from this user test.

INTRODUCTION
During the last ten years the landscape for mobile devices has changed drastically, with advances in MP3 players and PDAs, followed by smart phones, then tablets and now smartwatches [30, 20, 18] The smartwatch has received renewed interest, with the launch of the Apple Watch in April 2015 [19], following on the success of the iPhone and the iPad [15]. While there are some reports that the Apple Watch is not as popular (around 5% of smart device owners having bought a smartwatch) [15] the smartwatch form factor does present some interesting new opportunities for design. In a study by Pizza et al. [24] test users wore cameras to analyse their use of the Apple Watch. That study revealed that 50% of all interactions used the watch's basic functionality as a timepiece, i.e. they did not utilize the smart functionality of the watch. This suggests (along with the history of watches broadly) that visualising the time might be a valuable and perhaps neglected use for technology. Indeed, this work also identified different uses of timekeeping including prospective and retrospective uses of the time.

Accordingly, this paper looks closer at timekeeping and how self-tracking features can be used to create a personalized clock for the user. The purpose is to explore an alternative to the traditional analogue or digital clock, and how this could be incorporated into smartwatch design.

One alternative to clock time is egocentric time, discussed in the work of Ernst Pöppel [25] and Robin Le Poidevin [21]. From an egocentric perspective time can be divided into three different categories: past, present and future. This way of perceiving time puts one's self in the centre, hence the name egocentric, and it resembles how humans categorized temporal information. This gives a different perspective on timekeeping – rather than objective clock time (such as 4:44pm), there is a subjective egocentric time perspective – what I did earlier, what I am doing now, and what I will do next. This paper focuses on how this perspective can be used to redesign the clock face.

The paper starts with an overview of the history of time-keeping and the clock itself. It then present two different design directions for a new smartwatch time application, presents a technological review of how it could work and a prototype of the final design, complemented with a discussion on the design decisions made. It concludes with a discussion of future work on new interfaces to time.

BACKGROUND
This section covers how timekeeping has evolved throughout history, how time is perceived and how a person's movement can be tracked and predicted.

Humans have been keeping track of time for a long time, the first known record of a timekeeping device dates back to around 1500 BC in Egypt [32]. The Egyptian shadow clock had a semi-circular shape that were divided into twelve parts, as seen in Image 1. Each of the twelve parts were further divided into more precise parts. Due to the unreliable nature of shadow clocks the Egyptians also developed other devices for time measurement, most notably water clocks and devices for tracking star movements. These devices were used for two reasons, to track a specific period of time and to track time during the night respectively. [8] The development of timekeeping devices further progressed in ancient Greece. They utilized both water clocks and sundials, and in some cases both. One of the most famous timekeeping devices from ancient Greece is the Tower of the Winds, it is a clock tower constructed in Athens. The Tower of the Winds contained nine sundials, a water clock and a wind vane [5]. Water clocks were commonly used in ancient Greece and that tradition was later passed on to the romans as well [17]. The most notable improvement of the water clock was made 325 BC when a clock face was added as well as a hand indicating the hour. The use of water clocks was not unique to Egypt and Greece, it was in fact the most common timekeeping device in Iran, Persia and China as well [13].

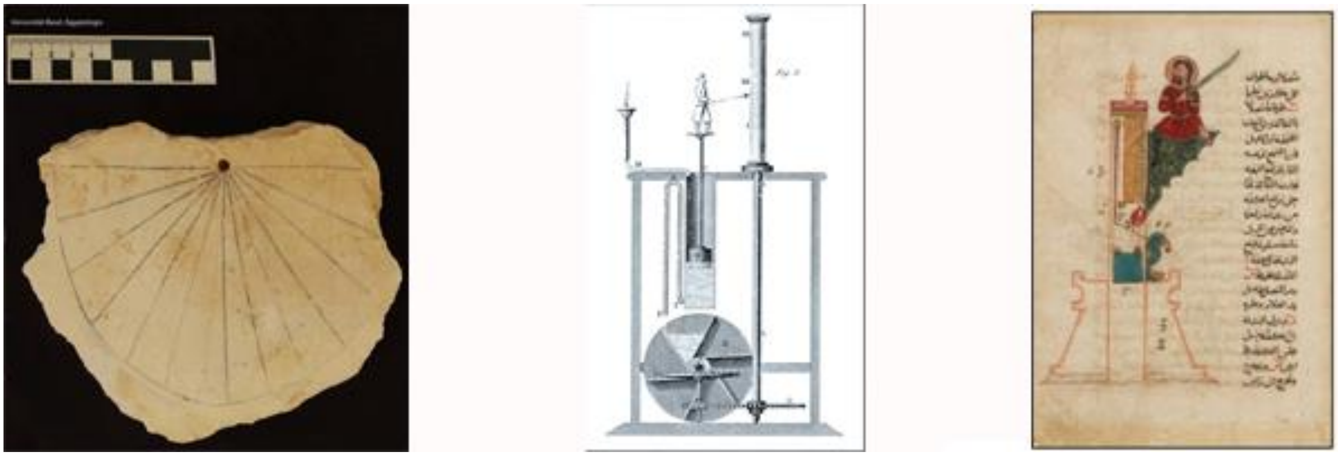


Image 1: The oldest Egyptian sundial discovered [32], an ancient Greek water clock with circular clock face [27] and one of Al-Jazari's candle clocks [31].

Around 500 AD candle clocks began to appear, similarly to water clocks they measure the passing of a certain period of time [4]. The most advanced candle clock was created around 1200 AD by Al-Jazari, it featured a circular watch face and hands showing the hour [17].

Between 1348 and 1364 Giovanni Dondi dell'Orologio created the Astrarium, one of the first mechanical clocks in Europe. It featured seven different circular clock faces that visualized the position of the sun, the moon and the five known planets as well as religious holidays [14]. During the early 1400s the clock became truly portable and available for domestic use and in the 1490s the mechanical watch simultaneously appeared in Italy, France and Germany using the same fundamental mechanics that were used the next 500 years [29].

Between the 1500s and the 1970s watches were improved upon significantly, increasing accuracy, reducing the need for winding up and making them more portable. In addition to all of these clocks there are many more timekeeping devices such as the pendulum clock, the chronometer, the quartz clock and the atomic clock.

All the different timekeeping devices can be divided into two different categories. The first one tracking the time of the day such as shadow clocks and wristwatches and the second one tracking a specific period of time such as candle clocks, water clocks and chronometers. Many of the devices in the second category has been adapted to track the time of the day as well.

There is one thing that has been central to the design of watch faces throughout all time, they are circular. The basic look of the watch face has remained very similar throughout the last 3500 years. While the first shadow clocks were semi-circular to mimic the sun's semi-circular movement, many of the later ones are circular. The circular design has since then influenced the design of watch faces and it still apparent in watches today. The largest deviation from the circular watch face is the mechanical digital watch which first came in the 1920s and but was not popularized until the 1970s when the electronic digital watch arrived [29]. The digital watch replaced the watch face and displayed the current time with numbers instead.

Time perception and Humans

How humans experience and perceive time is topic of psychology and it is a question that does not have a clear answer. Ernst Pöppel argues for the fact that there is no such thing as time perception. That time is a subjective matter and we experience time through the perception of events. He argues that the events in one's life are organized chronologically on a large scale, i.e. one can remember that certain events occurred when one was a child but it can be difficult to remember the correct order in which the remembered events occurred. The strength of the chronical details of a memory depends on five different, as Pöppel named them, elementary time experiences. These following five experiences make up the subjective present [25]. The five elementary time experiences are:

1. Duration
2. Non-simultaneity
3. Past and present
4. Change of time
5. Passage of time.

By duration Pöppel means how well a person is able to determine the time elapsed between events, if the perceived duration between two events is small enough both events will be attributed towards the same subjective present due to them occurring subjectively simultaneously. This also ties into the second experience, non-simultaneity which is the ability to remember that two events did not occur simultaneously. Past and present defines the ability to determine sequence and the "*feeling of newness"*. Change of time describes the speed at which time is flowing, whether it is fast or slow. Passage of time has to do with if time is moving faster or slower that what is perceived.

To further expand upon the term subjective present, one can look at Robin Le Poidevin's article defining egocentric and objective time [21]. The article defines the egocentric and objective distinction for time based on previously established rules for egocentric and objective space. Objective time is time seen from an outside perspective, with no relation to one's current position on the timeline whereas egocentric time is oriented around the self. Le Poidevin exemplifies this by classifying several different temporal descriptions as either egocentric or objective. From an egocentric perspective on time, everything can be organized into three different groups: past, present and future, which is similar to how we organize events in our minds. When describing a point in time from an egocentric perspective one can use phrases such as "*In 2 hours"* or "*Tomorrow"*. To describe a point in time from an objective perspective one has to use phrases such as "*On the 5th of June 2016"* or "*At 15:00 GMT on the 9th of February 2013"*.

User tracking and movement prediction

Together with the rising interest in smart mobile devices and quantified self products come an increasing requirement for accurate user tracking and movement prediction. In a paper by Ashbrook and Starner [3] a system is suggested that automatically clusters GPS data into meaningful locations. It is then suggested that this information is used to fill a Markov model in order to provide insight into future movements for the user in question. In their study they tracked their users through a GPS receiver that always was active. It did however only broadcast whenever the user was moving at one mile per hour or greater speeds. Based on that they arbitrarily decided that if the user had not moved in ten minutes or more, that location should be regarded as place.

GPS trackers are not entirely precise, the same physical location can vary by seven meters on average when using A-GPS. A-GPS is the most precise technology for tracking mobile devices but it comes with flaws, most importantly it does not function indoors. When inside a building, in the subway or similar indoors locations one is limited to WiFi or Cellular positioning which comes with a median error of 74 and 599 meters respectively [7].

Because of these precision issues Ashbrook and Starner ran their location data through a k-mean clustering algorithm to more accurately determine the places that their user had visited. They suggest that the number of clusters should be determined by plotting number of clusters found per cluster radius in a line graph and use the value just before the number of locations begin to converge to the number of places. In the Ashbrook and Starner study they used data gathered over four months to determine their movement probabilities. They also did not account for which day of the week nor at which time of the day the data was collected. A paper by Cho, Myers and Leskovec [7] presents movement data and analysis of said data based on both cellular tracking and location gathered through the social networks Gowalla and BrightKite. They present a correlation between long-distance travel social network ties that were not present when looking at shorter distances. They also present a correlation between likeliness of a check-in and distance from home.

Another way of reducing the necessary amount of data to determine where a user goes is presented by Atzmueller et al. [2]. In their study they utilize RFID tags and RFID readers to track their user's physical and social activities. This method for tracking users also have the benefit of being able to differentiate between different floors of a building.

A paper by Hightower et al. improves upon the work Ashbrook and Sterner did by using other location indicators besides GPS to gain increased accuracy [16]. They utilized 802.11 and GSM radios that many mobile devices have built in to track devices and recognized locations. Using their BeaconPrint algorithm they can recognize a place after the first time a device goes there. Their algorithm improved accuracy for place learning and recognition to over 90 %. They used to the MAC-addresses of Wi-Fi networks in a way that resembles the use of RFID tags presented by Atzmueller et al. to confidently determine specific locations.

The Quantified Self

The area of self-tracking and through that self-enhancement is one that has grown simultaneously with the smart devices [10]. With every new generation of devices they are upgraded with both new sensors and upgraded old ones. Smart devices today contain technology capable of tracking movement, sound, light, temperature, moisture, location and heart rate. In addition there are peripheral devices that further allows users to self-assess, e.g. MobiSante [22] and CellScope [6]. This area, or movement, is commonly referred to as the quantified self, i.e. using self-knowledge through self-tracking with technology towards self-enhancement.

The most popular applications for self-tracking are from the following categories: Health, Fitness and Lifelogging, and many fits in several categories. The most popular applications include [26] the following ones.

Fitbit, a family of small devices for tracking physical activity or sleep. [12] Digifit, a suite full of self-tracking applications distributed by Apple. It contains six applications dedicated to tracking different parts of one's daily life. [11] RunKeeper, a mobile application for tracking and measuring runs. It tracks distance, duration, speed and calories consumed coupled with several different tools to motivate you and further enhance your run. [28] DailyMile, a social work out-sharing site that connects to different devices to share your workout routines with others connect to the same network. [9] Moves, an activity diary of your life, measuring and tracking when you move, how you move and the duration of your move, creating a daily diary of your life with emphasis on motivating a healthy lifestyle. [23] Activity, an application created by Apple that comes pre-installed on the Apple Watch. It allows the user to set up goals for 3 different metrics for each day of the week. It has one goal for standing up, one for burning calories and one for exercising. [1]

Research Question

Taking all of the above background information into account the following research question was formulated:

How do one visualize time from an egocentric perspective in a way that attempts to challenge the design of traditional timekeeping devices?

DESIGNING A NEW WATCHFACE

Based on the information presented in the background section the design proposed in the next parts of the papers will be oriented around presenting time from an egocentric perspective due to it resembling how time is experienced and perceived more closely compared to how regular clocks present time.

Design Goals

The main goal for the project was to design an application for the Apple Watch that presents time from an egocentric perspective. In order to further structure the work, the three following design goals were set up:

- Present the time for the user from an egocentric point of view.
- Allow the user to know what to do and when to do it without providing objective time.
- Provide a useful functionality without depending on user interaction in order to simulate the usage patterns of a regular watch.

The goal is for the application to not limit the user in a way that makes him/her feel dependant on a regular clock as well, it should provide a sufficient alternative. It should not de dependant on the user setting up his/her own schedule more than the user already does.

Design Influences

The largest source of influences comes from a project called Visualizing Time [33] in which 324 people of all ages were asked to submit a drawing or sketch of their perception of time. Quote 1 shows their own description of the project.

"*How do you see the passage of time? Many people we asked draw something immediately, as if they always knew, even if they had never thought about it before. What emerges is an unexpected variety of visuals ranging from minimal abstractions (dots), to lines, to circles and surfaces, and beyond to complex symbolic forms*."

Quote 1: Description of the Visualizing Time project [33]

The results of the Visualizing Time project take almost any shape or form. In order to gain a better understanding of how humans visualize time I conducted an analysis of all the drawings available within the Visualizing Time project. During the analysis, two different perspectives on time became apparent, I decided to name these two perspectives Constant and Cyclical.

The visualizations that were categorized as constant were the ones which described time as something moving in a direction, sometimes it had multiple possible directions but it was a movement from beginning to end. In some cases the beginning were infinitely far away and the end just as far as well, in others it was simply the span of a life time.

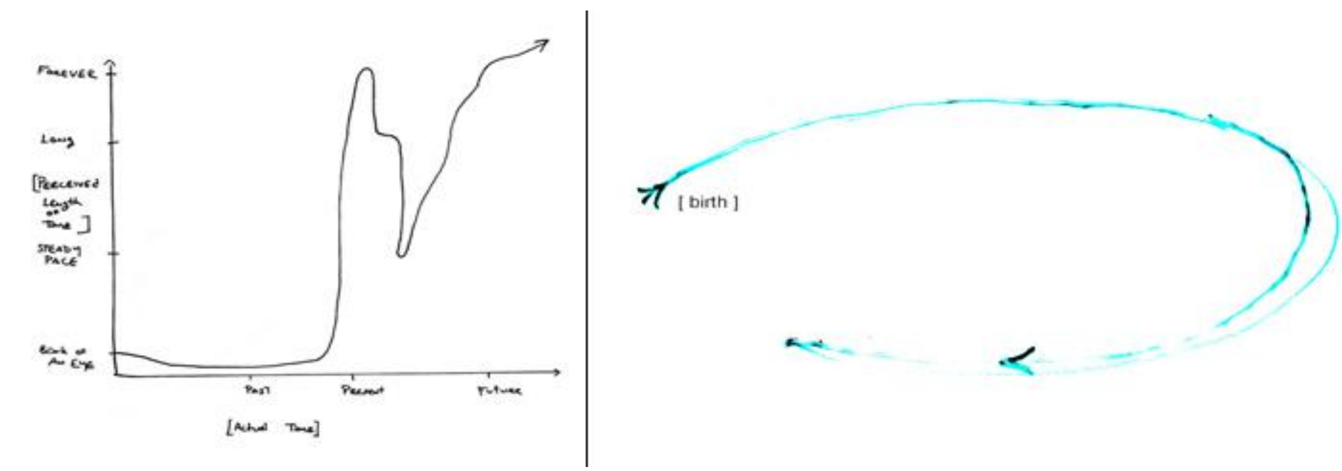


Image 2: Left: A visualization categorized as constant. Right: A visualization categorized as cyclical.

The left side of Image 2 depicts one of the visualizations that were categorized as constant.

The cyclical visualizations described time as something that goes in circles. It could be the seasons coming and going, the sun rising and setting or the daily list of tasks that is finished every day yet fills up overnight with new duties. One of the cyclical visualizations can be to seen to the right in Image 2.

The Other category is deceptively large since it collects all of the visualizations that fit in neither constant nor cyclic. The contents of that category is wide and incoherent, fitting in neither of the categories nor do they visualize time in a way that is relevant to this project.

The design work for the project was split up into two different directions, one for each of the two visualization categories. In addition to presenting the time from an egocentric perspective to the user, several of the designs attempt utilize the information gathered about the user further and visualize a secondary information set.

The next two sections will present six different designs created through sketching with various other timekeeping devices as inspiration.

Constant Time Designs

Many of the visualizations that were categories as constant took the shape of lines and arrows pointing towards the future. Therefore, the designs based on this way of perceiving time are focused on resembling a timeline in different ways. The three constant designs can be seen in Image 3

Design 1.1

The first design solely consists of a vertical progress bar that visualizes the time progressed for the activity the user is currently doing. When the bar fills up to the top as time progresses, reaching the top at the point when the next activity is due to begin. The speed at which the bar fills up is dependent on the length of the activity, this removes the connection to objective time completely. This design is directed completely towards the current task at hand and sacrifices giving overview of different tasks and activities for simplicity. It uses both colour coding and icons to identify the current activity. The design is inspired by traditional water clocks, candle clocks and time glasses which all were used to track a specific amount of time.

Design 1.2

The second design provides an overview of the activities for the entire day, with a vertical progress bar for each activity undertaken. In addition to visualizing the relative length of each activity, it also presents a secondary information set. The distance from the left edge of the screen is determined by the real world distance between the user's home and the location for the activity. This design attempts to push the boundaries for what can be visualized on a clock face without cluttering the interface. The second design does not use icons to indicate activity type in order to not fill up the interface entirely. It draws its inspiration from calendars and schedules rather than clocks. As time progresses a line moves across the current activity changing the activity to grey to indicate past activity.

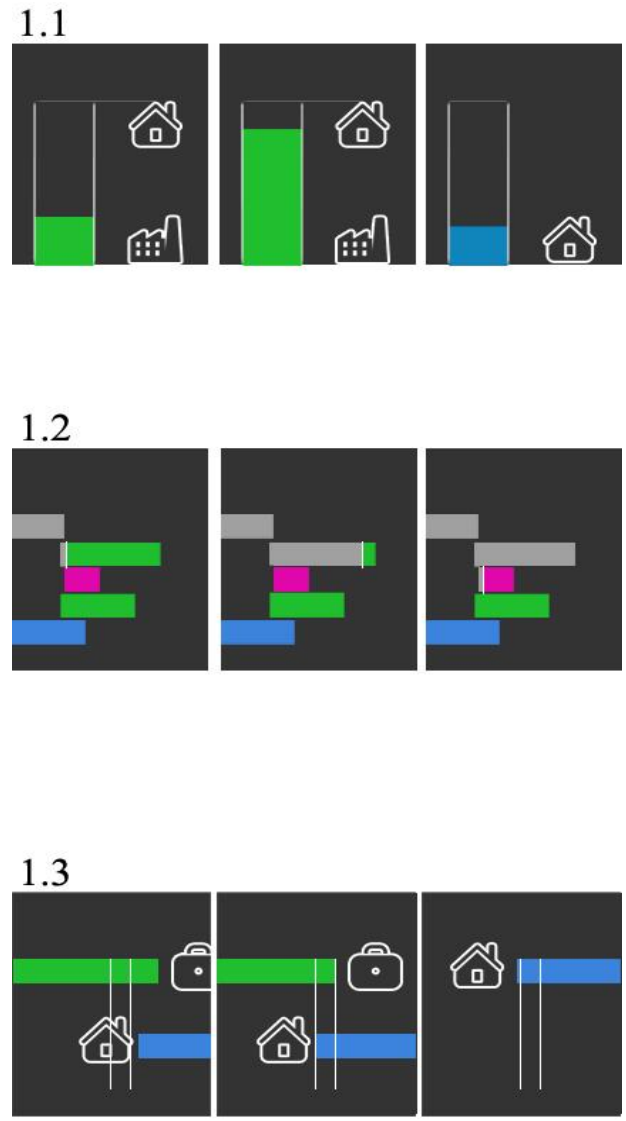
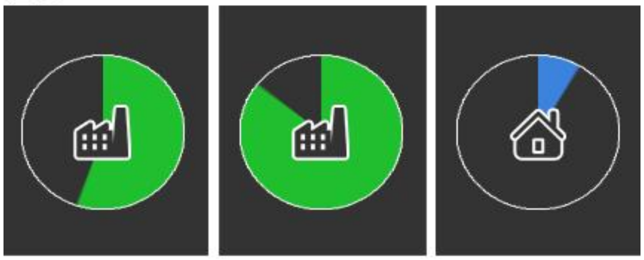


Image 3: The three designs based on constant time perception. Visualizing time with a progress bar, a two dimensional timeline and side scrolling timeline respectively.

Design 1.3

The third design emulates a flowing horizontal timeline with the user's location constant in the middle of the screen. In a similar vein to the second design this one does also use an overlapping window between activities to both account for uncertainty within the system as well as travel time. It is the design that resembles a timeline the most. This design is in part inspired by Pöppels visualization of the subjective present as a continuous time lime with the middle section representing *right now* (highlighted with two vertical white lines). [25] Whenever the system detects that a new activity is started that activity’s bar would be moved up to the top of the screen, to make it clear which activity is currently the active one.

2.1



2.2

2.3

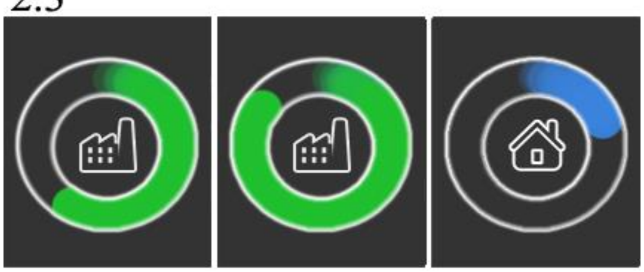


Image 4: The three designs based on cyclical time perception. Visualizing time through a closing circle, a circular timeline and a circular progress bar respectively.

Cyclical Time Designs

While the cyclical category were significantly smaller than the constant one, the designs inspired by this way of perceiving time takes inspiration for a variety of other different time representations, most importantly from clocks. These designs were made with the fact that clocks have retained their cyclical shape for 3500 years in mind, a fact that is not easily discarded when designing an interface to time.

Design 2.1

The first cyclical design visualizes the current activity through a closing circle. It indicates the type of activity through both colour and the icon in the centre of the circle. Even more than the design 1.1 it sacrifices overview for clarity as it only provides information about the currently ongoing activity in order to make it both easy and fast to read. As the activity progresses the colour sweeps around the circle and when it is complete it transitions to the next activity. The inspiration for the design comes from stopwatches and similarly to design 1.1 the functionality resembles the one found in candle clocks and water clocks. Similarly to design 1.1 the speed of the time flow in this visualization is relative to the length of the activity, removing further connection to conventional timekeeping. This way of tracking time puts a focus on Pöppels 4^{th} and 5^{th} elementary time experiences allowing the users to get a better feel for how fast the flow is currently perceived.

Design 2.2

The second design provides an overview of the entire day along a circle. Each activity throughout the day is colour coded while an icon is displayed for the currently active one. It attempts to capture the cyclical nature of the day, that each day mostly follows the same patterns. In contrast to both design 2.1 and design 2.3 this one also visualizes the relative length of each activity to further provide a better overview of how one spends one’s time. In this design, time flows at a constant rate which increases the similarities between the design and a conventional watch. The current activity is marked with a black line that travels around the clock face. This face allows the user to see how much time is spent on each activity relative to each other puts more focus towards Pöppel’s 1^{st}, 2^{nd} and 3^{rd} elementary time experiences instead, enhancing the user’s perception of in which order activities occur.

Design 2.3

The third design follows the same basic principle as the first one, focusing on the current ongoing activity instead of providing an overview. This design uses a ring that completes instead of a circle, inspired by the design of Apples Activity app. While similar to design 2.1 there is one difference in the visualization that provides a useful function. In this design the end point for each activity is not as strict. It is visualized by the fading tail of the activity and the purpose is to represent both uncertainty within the system but also, perhaps most importantly, that humans are not always on time. Our routines and movements can vary due to a myriad of different variables. The intention here is to provide the time in a more natural way.

Selection of Final Design

For the selection of the final design, the first decision stood between constant and cyclical. The cyclical designs have as previously mentioned time on their side, with two out of three resemble the early sundials. Since both the designs and the sundials worked as timers, filling up until it was time to leave work. While people today have more going on in life than only work, the basic principle remains the same.

Despite the long history and the tried and true nature of clocks, the constant designs were chosen. The main reasoning for this is that this design attempts to distance itself from regular time measurement and time visualization by providing an interface that to a larger extent resembles how humans perceive time. Looking back at Le Poidevin's [21] distinctions between egocentric and objective time I would argue that the egocentric terms more closely represent how I think about and perceive time. Removing the translation from objective to egocentric was part of the purpose with this project and while not everyone's egocentric time looks the same, the analysis of the Visualizing Time project showed a clear favour towards constant over cyclical time.

When it comes to the different constant designs the first decision stood between simplicity and overview. Design 1.1 representing maximum simplicity while design 1.2 represented maximum overview while the third design was somewhere in between the two. The decision was made in favour of design 1.1 and 1.3 after reviewing all three on the Apple Watch. The small screen size of the watch makes design 1.2 impractical since reading the time should be quick and effortless. Despite the relatively simple example provided in Image 3 the interface felt too tiny. The lack of icons also reduced the readability of the interface which would increase the learning curve. Another thing that affected the choice is that the design is intended to replace the clock, not the calendar. Looking at one's entire day each time one checks the time felt unnecessary

Between design 1.1 and 1.3 the initial design goals were revisited:

The Design Goals Revisited

Present the time for the user from an egocentric point of view

Both designs fulfil this criteria, design 1.1 does however inform the user of the progress relative to the length of the activity, while design 1.3 visualizes where on the timeline the user is.

Allow the user to know what to do and when to do it without providing the time

While both designs indicate what the next activity is, design 1.3 provides additional information about it. Information that could potentially affect how the user acts such as the duration of it.

Provide a useful functionality without depending on user interaction in order to simulate the usage patterns of a regular watch.

Neither of these designs rely on further interaction in order to understand them. The amount of user interaction required to set up the system is not related to the choice of interface design, all of the designs were made to fit the same backend functionality that were described earlier.

The Winning Design

Based on the review of the design goals the final remaining design is design 1.3. It provides a good middle ground between overview and simplicity. It allows the user to both understand where he/she is on the timeline and give enough information about what is going to happen to allow the user to adapt to any potential changes. One of the factors outside of the design goals that set it apart from design 1.1 is that design 1.3 moves at a constant pace. The speed at which design 1.1 fills up is dependent on the length of the activity.

Design Weaknesses

One weakness with the design is that whenever a new activity begins, the user may not see how far away the end of that activity is. The prototype does not allow for horizontal scrolling in order to remain a watch and not become a schedule.

Another weakness is the fact that there is no regular clock in the design and despite what the purpose of this project is, there are circumstances when you need to know the time. Especially when taking other people into the equation, since it provides the users egocentric time.

As mentioned, a solution to the first weakness would cause the project to diverge from the initial goal and further distance it from watches. The second weakness is solved through the Apple Watch. Similarly to the iPhone, the Apple Watch also have a status bar that contains a clock.

DEVELOPING A PROTOTYPE

Capabilities of the application

The functionalities presented below form the basis for what the application is intended to be capable of and subsequently it assists in deciding whether a design is fit for the system or not.

The main functionality of the application is to constantly track the user's location. This is achieved by using the *significant-change location* function from the *Core Location Framework* to the iOS. The *significant-change* is used instead of the standard location tracking to save battery power. The data gathered is then clustered using K-Mean clustering to calculate the places the user has visited. Similarly to the study by Ashbrook and Starner [3] mentioned previously the users movements are then used to create a Markov model that can be used to predict future movement. In the aforementioned study the Markov model did not contain any information about the time of the movement. For this application however, different tables would be created, differing between weekdays and weekends and when a sufficient amount of data has been gathered, between each day of the week as well.

In order to make this application work for those with a less regular schedule, it should be possible to connect calendars from external sources. The events imported from those are put in a priority queue, alongside the predicted events. The events in the queue are prioritized ahead of the predicted events when drawing the interface to make sure that those activities are not missed.

Design Refinements during prototype development

In order to develop a prototype to the Apple Watch featuring any of these designs, refinements had to be made due to the Apple Watch interface being limited in what it allows the user to do. These interfaces would have to be dynamically created since it would be impractical to create images for every possible layout for each design. Therefore several things had to be considered. First of all, the watchOS2 interfaces only have three components: images, groups and text. Neither text nor images were particularly useful during the majority of the development and therefore groups were all that remained. Groups function as boxes that can be placed within each other, they can however never be larger than their parent and they are all positioned relative to each other meaning that two sibling groups can never overlap each other.

There are also weaknesses imposed by the watchOS2 and the Apple Watch. Apart from the limitations discussed above the Apple Watch does not allow this sort of modification to the watch face. It would have to be run as a regular application to the watch, meaning that if the screen is turned off during a short period of time the watch will default back to the watch face again. There is no way to make the application avoid this inherently, instead it has to be set up by each user by changing the Activate on Wrist Raise setting to Last App Used. This still requires the application to be the last one used each time the screen is turned off.

The Prototype

The prototype was developed in Swift for the Apple Watch using watchOS2. The prototype that was tested resembled the final design closely as seen in Image 5. The watch prototype was built without any movement tracking functionality, instead the schedule was hard-coded into it. The prototype displayed 30 minutes of the user's timeline of the watch face, showing 15 minutes in each direction from the current time.

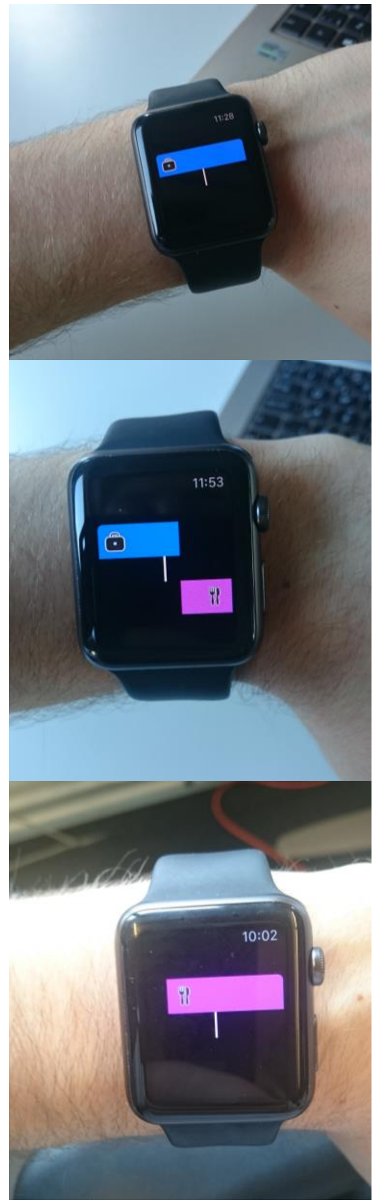


Image 5. The finished prototype displayed on the Apple Watch. The images show the progression from work towards and into lunch.

In addition to the watch prototype, a basic prototype for evaluating the functionality of the *significant-change* functionality of the *Core-Location Framework* for the iOS was developed for the iPhone. The prototype implemented the k-mean clustering algorithm presented on excode.io and used pre-determined initial clusters to avoid the need for a long data gathering process.

Preliminary Evaluation

In order to generate initial feedback on the prototype one person used it for 48 hours. The prototype was setup with the test users location based on a predetermined schedule for that time period. It did not feature events that did not cause a shift in location. The tested schedules consisted of the following activities: Home, Work, Lunch, Work, Gym and Home. After the testing period feedback were gathered through an open interview during which the test user were asked to provide any thoughts or opinions regarding the design.

Evaluation Results

There were two main takeaways from the preliminary evaluation. First of all, the timeframe shown on the clock was too narrow. When the next activity came into view there were not enough time to travel to it in time. This also ties into the second problem, namely that the interface was to uninformative whenever only one activity was shown. In comparison to looking at a regular watch the prototype provided less information when glancing at it.

Based on the feedback gathered in the brief user evaluation the prototype was updated to provide more information at all times and by extending the time frame shown. The updated version provides information about what the next upcoming activity is and how much time remains. A comparison between the new and the old can be seen in Image 6.

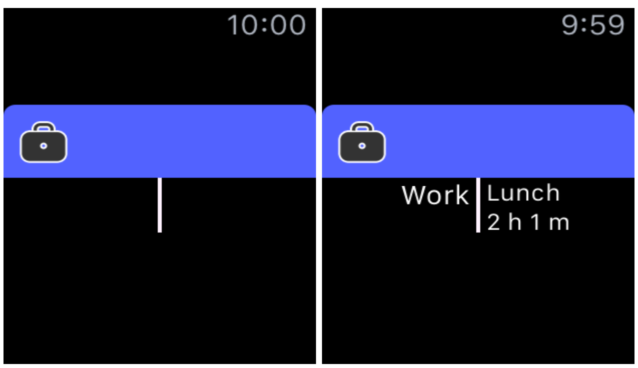


Image 6. Comparison between the application before and after the user test.

The location tracking iPhone prototype was able to determine when the user reached a pre-determined location with the use of the *significant-change* function. Based on the work by Ashbrook and Sterner [3] and Hightower et al. [16] it is unlikely that only using *significant-change* is sufficient to build a model for the user's movement patterns due to not providing information on a regular basis.

One factor that might have affected the evaluation in a way that favours the design work is that the status bar of the Apple Watch contains a watch providing objective time. In retrospect however, I do not consider this a flaw in the design. Being able to tell time from an objective perspective as well allows the user to interact with others in a way the current design does not allow. This was also touched upon during the evaluation, the test user expressed concern that using an egocentric watch would make it more difficult to discuss time related matters with others. I think that this is a legitimate concern and defiantly something that has to be kept in mind when working with egocentric time. The intention of this paper is however not to argue for egocentric time as a replacement for objective time, I simply want to use the concept to provide a more natural interface for ordinary timekeeping.

Ethics and Sustainability

Constantly tracking a person's location can easily be seen as a violation of personal privacy. In order to avoid this the application should attempt to only store pure location data in the iPhone. Depending on the intensity of the necessary calculation required to properly predict the movements of the user a cloud based backend might be required. In that case it would be enough if the application only communicated names for each location and not the GPS-coordinates. In addition, each user should not identified with their phone number or email address, instead the application should create a randomized username for internal use.

This design would not have any measureable impact on sustainability related discussion, regardless if one takes an economic, social or environmental perspective. This is because none of the described functions nor technologies requires much of anything in order to become reality.

Future Work

While these designs are created with people's perception of time in mind it is not guaranteed that the final design, nor the others, are what the user would want in the end. Therefore the next step would be to arrange a user study over a longer period of time with a larger amount of users. The users should preferably also have varying time schedules in order to test the functionality in as many situations as possible. The k-mean clustering algorithm and the location tracking functionality would also require further user testing to determine what technology should be used and how to most efficiently determine locations for the purpose of this application.

CONCLUSION

The application presented and discussed combines the technology behind the quantified self movement with a regular wrist watch to create a new way to measuring one's own time. The application presents the time of the day based on the user's routines and movements through user-tracking and future movement prediction.

The analysis of the Visualizing Time project revealed that a relative majority view time as something constant. Not in the sense that it stands still, instead time is viewed as something with a beginning and an end, constantly moving forward at a steady pace without regard for anything else. About a fifth of the participants visualized time as something cyclic such as clocks or seasons of the year. Based on these different perspectives of what time is and how it looks six different designs were created and after a discussion a final design that best fits the purpose was chosen. The final design consists of a horizontal timeline with vertical gaps to indicate when different activities begin. The timeline progresses at a constant pace through the day.

In closing I would like to argue that there is room for an application such as the one discussed in this paper due to that a relative majority did visualize time from a perspective which is different from how traditional timekeeping devices do.

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