New Representation of Time: Design and Implementation of “Free Time”

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Abstract: To visualize time, we currently use tools such as calendars, clocks, watches and timers. These tools were originally physical, however as we move into a digital world, digital versions of these tools have been created. Digital versions of time visualization tools however are almost identical to their analog counterparts. This paper proposes three applications to replace traditional timekeeping tools. Each application discards a convention of timekeeping to offer improved user customization. The first is a scheduling application that discards fixed time viewing ranges. It is a variable range/precision tool that allows users to zoom and pan their schedules, and can be used as a clock or calendar. The second is a productivity application that discards traditional time divisions. Instead of 1, 5 or 15-minute markings on a 60 minutes face, the application allows the user to define the duration of both the full cycle, and its divisions. The final application is a punctuality application that discards traditional durations of time, it allows the user, in certain situations, to speed up or slow down their watch. By putting previously standardized conventions in user hands, tools that allow the user to view time as it pertains to their schedules and activities, and act or modify behavior using more relevant information than is available in traditional timekeeping tools.

1. Introduction

The usage of time can be roughly divided into three range categories, short, medium and long. When time is used on the order of milliseconds, seconds and minutes, it is being used to increase precision. When sprinters run a close race, precise millisecond based measurements in time are used to determine the winner.

The middle range of time is measured from hours to days. This range is used to organize and schedule. As schedules are often shared, this range of time needs to be referenced by multiple parties in an understandable way.

The long range of time extends both into the future and the past. It is used to record and plan. This range of time is viewed with less precision as the short and mid ranges. When we learn history, we learn about major past events, and not the hourly schedule of someone’s day. The further in the future we plan for, the less specific we can be about when the plan will happen.

Multiple analog tools were created to accommodate the variety of time ranges. Stopwatches and timers are used to measure time in the short range, clocks and day planners are used for the mid range, and finally calendars and timelines are used in the long range. It is these tools that our applications seek to improve.

As hardware and software are continually improved, timekeeping interfaces are also due for redesign. Timekeeping tools are used by almost everyone, however there is little customization and evolution in the most widely used tools. Most digital iterations of timers, watches and calendars are direct translations of their analog counterparts. Smartphones for example still display digital numeric or analog watch faces and the layout of online calendars look exactly the same as paper printed wall calendars.

With the power of new digital platforms, it is possible to redesign timekeeping tools to be more user oriented, this can be done by giving the user control over previously standardized conventions. To build new time tools, we have identified three uses of time to created improved tools for. These uses are 1) time scheduling, 2) productivity, and 3) punctuality. In the process of creating applications for these uses, we challenged three conventional standardizations of analog timekeeping tools. These standardizations are 1) the range of viewable time, 2) the divisions of time, and 3) the speed at which time is measured. In this research, we seek to create more user oriented time interfaces by allowing traditional standards to become variable, and by putting control of these variables in the hands of the user.

2. Related Works

As timekeeping devices move to digital platforms, much extended functionality has been added. Watches can now encourage fitness and warn of health complications, and calendars can smartly schedule appointments according to availability. However when looking at digital versions of analog tools, activity trackers or full fledged smart watches, it can be seen that the digital evolution of timekeeping devices has focused on extending functionality related to user inputted content, or adding non timekeeping functions to the device, and the visualization of time has been left largely unchanged.

2.1 Digital versions of traditional timekeeping tools

With the proliferation of smart devices, more and more tools for timekeeping, time visualization and behavior modification are appear on digital platforms. Smartphones now have digital versions of clocks, timers, alarms and stopwatches. Day planners and calendars have moved online. Recreating timekeeping tools on digital platforms and online allow the user to view personalized versions of these tools across devices.

Currently personalization in digital timekeeping tools occurs in the way content is entered and shared, however the layout of

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content display has stayed similar to analog tools. Additionally categories of tools have been translated directly to a digital platform, print calendars have become online calendars, and analog clock faces are used in apps. The IOS [1] clock application for example uses a traditional analog clock face. Narayanaswami et al. [2] patented a way to more efficiently use screen space by changing a circular watch face to elliptical, and using the saved space to display extra information. The resulting watch face is still the same as an analog 12 hour watch, while our scheduling application proposes to display extra information using pan and zoom functionality, breaking away from the 12 hour standard.

Calendar systems especially have seen many advances in the aspect of entering, synchronizing and sharing schedules across devices and users, but not as much advancement in interface and layout of the calendar itself. The Google Calendar [3] has multiple tabs for daily, weekly and monthly planning, the design of each tab is similar to the printed versions of daily/weekly planners and calendars. Kanevsky et al. [4] patented a smart calendar in the form of a standalone touchscreen surface linked to the Internet for easy synchronization of schedule items. The patent focuses on creating innovative hardware to replace paper calendars with networked touchscreen digital calendars. Halang et al. [5] proposed an algorithm to help users create appointments with each other. The algorithm uses context data such as location and already scheduled appointments to calculate the best time for a new appointment. Shih et al. [6] proposed a similar system, however context data in this system is used to weigh the importance of schedule items, and organize personal schedules accordingly. Lee [7] proposed a system using context data, especially from the calendar, to provide additional information and personalization to the user. For example, the system is able to scan a corporate calendar event's information and remember a conference call number, conference id and pin for one-click entry.

In this paper we propose a scheduling application that does away with the separation between categories like clock and calendar using a new interface.

2.2 Activity Tracker / Goal Setting

Time visualizations aid the user by allowing better, more efficient use of time. Activity trackers use visualization to influence behavior by displaying progress related to healthy habits.

The Fitbit Force [8], Nike FuelBand [9], and Misfit Shine [10] are examples of popular activity tracker devices. All these devices use external applications to set activity goals, then measure user activity using built in sensors. Progress toward activity goals is then displayed as visualizations on both the device and smartphone. As these trackers are worn on the wrist, they are in the perfect position to act as timekeeping devices as well. The Fitbit Force and Nike Fuelband both have a screen that is able to display activity information while doubling as a digital watch. The Misfit Shine tracks activity through 12 led lights arranged around its circular face. When not used to track activity, these dots are able to act as the hour and minute markers of analog watch face. One of the 12 dots will switch on to represent the hour, and another to represent the minute, with the rest of the lights off. Though this means the watch is only able to approximate time to the nearest 5 minutes, the device is able to recycle its interface for multiple uses.

Though activity trackers are useful devices for modifying behavior, they focus on health and fitness, and their timekeeping functions are added as an extra feature. We would like to propose more generalized time tracking tools, which can modify behavior in a wider range of activities.

2.3 Smart Watches

The smart watches currently entering the wearable technology markets are either feature rich devices aiming to replace the smartphone, be a wearable extension of the smartphone, or even be useful in the medical field. Interface designs of these watches also vary greatly according to their intended function, many, like the Pebble [11] and Samsung's Galaxy Gear [12] feature touchscreens, while the Martian [13] line of smart watches resemble traditional analog wristwatches.

The Pebble is a successful example of a touchscreen smart watch. It features its own app store, though the store is still new, there are a few apps that allow users to customize their watches. The Glance [14] app allows users to show extra information such as weather, calendar or even stock quotes. The Canvas [15] app allows users to customize the way their watch faces look. Watches such as these are a good target platform for further iterations of our project.

The Martian smart watch line is an example of watches designed to be an extension of the smartphone. They feature a microphone and speaker to issue smartphone voice commands, and can display basic information, such as the weather. The watch also has a small display with which to receive notifications from a smartphone.

Smart watches are also being designed for non time related functions, Lockman et al. [16] proposed a watch able to detect seizures using the accelerometer, and Wile et al. [17] proposed a design also using the accelerometer to detect Parkinson's disease tremors.

Smart watches on a whole have focused on extending non-timekeeping related functionality, while leaving timekeeping interfaces similar to the traditional analog of digital numeric displays. When time visualizations are customizable such as in the Pebble, the user is only able to make cosmetic changes.

2.4 Non Timekeeping Interfaces

Time related interfaces used for non-timekeeping purposes were also valuable inspiration when creating our application. An example would be the Facebook [18] profile timeline.

In 2011 Facebook redesigned its profile page into a timeline that shows a chronological account of the user's Facebook activity, from their day of birth to their latest Facebook update. The interface begins as the present, and displays information further into the past as the user scrolls. The Facebook interface is not geared toward telling time, we propose a modified timeline in our scheduling application that is.

As can be seen from the above examples, there has been much innovation in the non-timekeeping capabilities of smart watches, and the intelligence of scheduling applications. With our applications we aim to contribute to the evolution of the core function of timekeeping devices, that of telling time.

2.5 Actionable data visualization

Timekeeping devices can be thought of as part of a category of interfaces that provide actionable context data at a glance. Other examples of this interface are speedometers, altimeters/barometers, radars and more. Pace et al. [19] proposed a new heads up display to encourage drivers to drive more efficiently. The display projects acceleration/deceleration data as well as fuel efficiency data directly to the windshield, forcing the driver to be wary of driving too aggressively. Kumar et al. [20] proposed an upgrade to traditional speedometers. The new design receives speed limit information of the current road and adds visual cues to the car speedometer. Example visual cues are the addition of a colored background marking red the speeds that are over the road limit, or turning the speed indicator needle red when the car is speeding.

Originally systems such as the speedometer were designed to provide information, however as technology advances, they are evolving to be able to dynamically recommend action based on context. Similarly, our range application aims to provide more relevant context for making decisions by allowing the user to see a self-defined time range, while the punctuality prototype changes behavior based on context.

3. Principle and Implementation

The objective of the applications presented in this paper is to increase the usability of timekeeping tools by allowing the user to customize the visualizations and interfaces of these tools.

Firstly, a variety of tasks that involve usage of timekeeping tools were chosen. Then, we aimed to create better tools for completing each task by giving users freedom where traditional timekeeping devices do not allow.

3.1 Scheduling Application

The scheduling application is a timekeeping interface that seeks to include the functionality of a variety of timekeeping devices. It allows the user to visualize a customizable view of the past, present and future.

In making decisions about how to use time in the present, the user should be able to reference relevant information in the past and future. Traditional analog watches and clocks have a standardized 12 hour view range, while digital numeric display timepieces are only able to show the current moment. Though perhaps physical limitations in analog watches created the necessity for standardized view ranges, watches built on digital platforms do not need to follow old conventions. On today's smart devices, timekeeping visualizations and interfaces are able to update according to user preference. It is possible to allow the clock face to display the range of time most relevant to the user. For example, a user is half an hour into a two-hour meeting. The relevant information for this user may be the time that has passed since the meeting started, until the time until the meeting will end. In this case the user's clock should begin half an hour in the past, to one and a half hours into the future. The relevant time range will vary user to user, if the user in the meeting must focus on a deadline an hour after the end of the meeting, they may be better served with a view range from the current moment until two and a half hours into the future. When the meeting or the deadline has passed, the user also requires the flexibility to readjust their viewing timeframe to the next most relevant range.

The idea of adjustable viewing ranges for time also has the potential to encapsulate a set of traditional timekeeping tools into a single tool. Currently tools we use to tell time can be categorized by the range of time that they serve. As mentioned, time measurement tools can be split into short, medium and long ranges. This separation of tools was previously necessary because of the levels of precision in which time can be viewed. Short-range timekeeping devices visualize time on a scale that would overload the user with information if used for long ranges. For example, stopwatch level precision provides too much information to be used to plan a vacation, which is why we use tools that display time more generally, like a calendar. On the other hand, a calendar displays information on a scale too general for timing runners.

The key to creating an all in one tool is to remember that time is continuous, and the separations in viewing ranges of our traditional timekeeping tools are due to tools being designed with limitations of technology. Allowing timekeeping devices to zoom and pan can solve the problem of variable time precision, because time is continuous, implementing this zoom and pan functionality in a continuous manner will allow the user to view all combinations of precision and range. Scheduling applications such as Google Calendar do have options to change viewing range. There are tabs to switch the calendar view to a day, week and month views, however these views are implemented discretely. Discreet views impose standardized compartmentalization on the user's time planning, and we aim to put compartmentalization of time fully into the user's hands.

In implementing the scheduling application we noted the similarity of displaying scheduling information to displaying location. Paper maps require separate prints to display location information depending on the precision required. Digital maps have solved this using zoom and pan interactivity, which updates the maps with relevant precision of information for each zoom level. Zooming out to a country level view for example, will hide data on street names. The time planning application uses similar functionality to display time.

The time planning application was created with web based programming languages, HTML, CSS and JavaScript. For this application it is important to have an external source of data to allow users to load scheduling information. Additionally, because we aimed to allow users to change the zoom level of time, we needed to handle changing precision and scaling of display data. We chose to use the D3.js library as it contains tools to handle data visualization and interaction. D3 also fulfills our visualization scaling requirements as it manipulates SVG.

We chose SVG over similar technologies such as HTML5 Canvas for its ability to scale easily, as well as the ability to assign attributes directly to SVG elements. As we use separate elements for schedule items, it is important to be able to easily edit each element according to its scheduled content.

The application consists of two horizontal bars one on top of the other **Fig. 1-1**. On initialization, both top and bottom bars display identical information, however their functionalities are different.

The bottom bar is a control panel. By clicking and dragging on the bottom bar, the user is able to specify a range of time they would like to focus on. After dragging, a box appears on the bottom bar to mark the selected range **Fig. 1-2**. This box remains after releasing the mouse, and can be dragged again afterward pan to the selected range **Fig. 1-3**.

The top bar is a display in which the focused range appears. As such after dragging, the bottom bar will still show the originally initialized full time range, however selecting an area in the bottom bar will cause the top bar to zoom into the selected time range. Interactions were designed such that a single button mouse is sufficient for all functionality, as this type of interaction uses a minimum amount of tools, and is easily translated to touch interfaces.

A black circle on both the top and bottom bars mark the current time **Fig. 1-4**. On the bottom control bar, this circle moves at a constant pace, however as the top bar displays zooming and panning behavior, its time marker moves according to zoom level.

Underneath both the top and bottom bars are a numerical timeline. As the visualization is zoomed and panned, the numerical timeline on the top display bar updates accordingly. Additionally, during zoom, the timeline is able to increase or decrease label precision and spacing. This ensures that at each timescale a relevant precision of time is displayed, and time labels are displayed with readable spacing.

The application currently loads scheduling information from an internal array. However it is also capable of loading external CSV or JSON files. Schedule items have text descriptions and color-coded backgrounds, both of which are defined by the external data source.

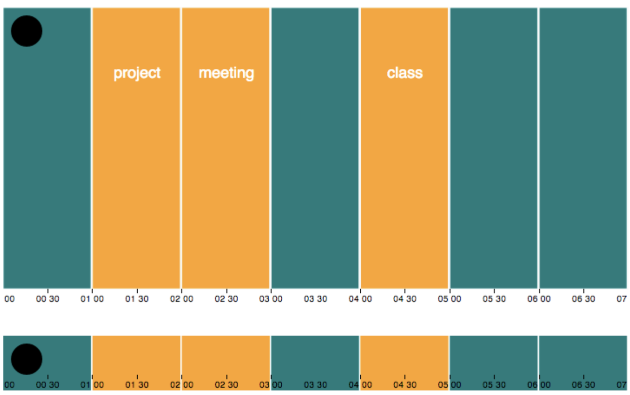

Fig. 1-1 Horizontal bar layout

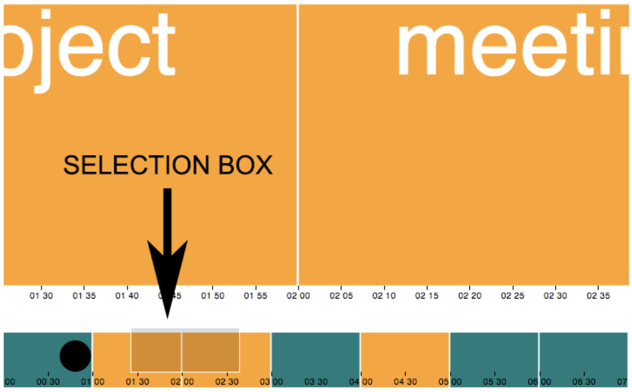

Fig. 1-2 Selection box

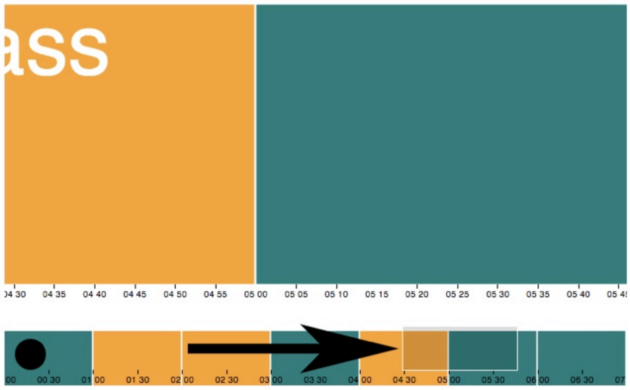

Fig. 1-3 Selection range panning

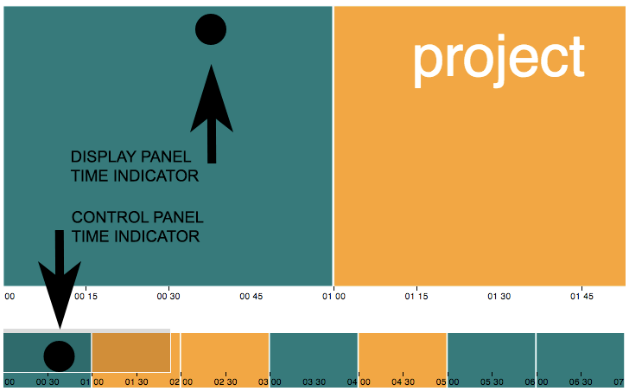

Fig. 1-4 Time indicators

3.2 Productivity Applications

Two scenarios in the productivity category were chosen as target tasks to create timekeeping applications for. These tasks are cooking, and work.

Cooking is an example of a single activity that actually consists of several multitasked mini activities. To cook efficiently, a chef has to simultaneously prepare several ingredients, keeping in mind the cooking time of each, while also being aware of the time when the meal must be served. The application for this activity was created to allow the chef to set individual timers for food items, while still having a normal clock display to allow show the total elapsed cooking time, and time until serving.

The application consists of layered timers that can be individually started. Each layer can be used to keep track of cooking times for a single food item. These timer layers surround a central core showing the current time. The central clock moves at a constant rate. While the outer timer rings are static on initialization. When each ring is clicked, they begin to rotate, counting the time **Fig. 2**.

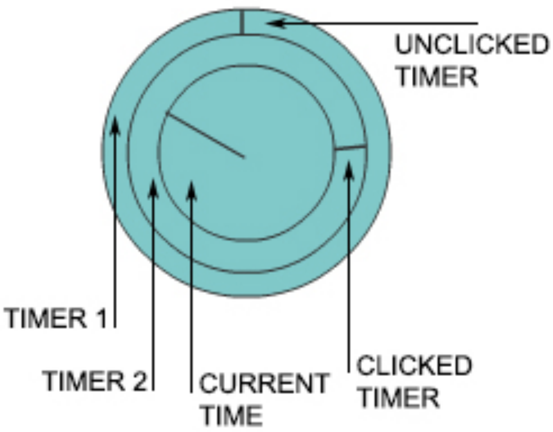

Fig. 2 Cooking timer layout

The concept of creating a layered visualization for multitask heavy activities was again used in the next application in the form of layered markers and alarms. We created time interface for a productivity/time management technique called the Pomodoro Technique [21].

When using the technique, the user divides long stretches of work time into 25 minute sessions of productivity separated by short periods of rest of 3-5 minutes. The technique aims to increase productivity by making sure the mind is rested. To keep track of work and rest intervals, this technique is used with a watch or timer.

The design uses a traditional circular watch interface with a dot to represent a full cycle of time **Fig. 3-1**; drawing from lessons learned in the time planning application, the user is able to define the length of a cycle. In the case of the Pomodoro Technique, a cycle may be 30 minutes, with 25 minutes of work and 5 minutes of rest. The dot marking the end of cycle is interactable, and can be used to mark divisions within the cycle. Again in the case of the Pomodoro technique, the user may place the marker near the end of the cycle to signal time for rest. The user can also click on the dot changing its color to red and functionality from just a marker to an alarm **Fig. 3-2**.

The Pomodoro Technique application increases productivity by allowing the user to divide time into user defined sections of work and rest. It is a specific example of a more general need, the need to easily divide time for more efficient use. Building the Pomodoro application required challenging a convention of traditional timekeeping devices, that of standardized divisions of time. Because our clocks display 12 hours and 60 minutes, it is easier to divide time into multiples and factors of those numbers. Our lives become compartmentalized by this convention. For example, we may schedule a 60 minute meeting, but not a 100 minute one. Traditional timekeeping tools have dictated how time is divided, when they should actually aid the user in dividing time according to need. Our application frees the user to define divisions of time as they see fit. Furthermore, not having predefined time divisions allows the user to more easily use approximations while planning. An example of this usage would be a worker with 7 equal length tasks to complete in a 6 hour work session. In this using circular shape of the watch as reference to divide time is much simpler than trying to calculate the required duration for each task.

Both the cooking and Pomodoro technique applications were created in Flash as the program provides useful tools for both animated visualization and interactivity.

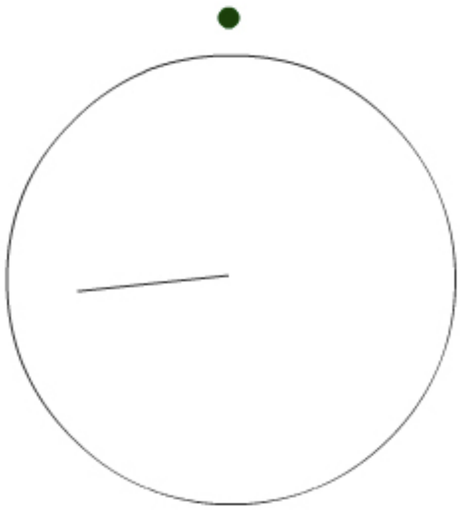

Fig. 3-1 Pomodoro application on initialization

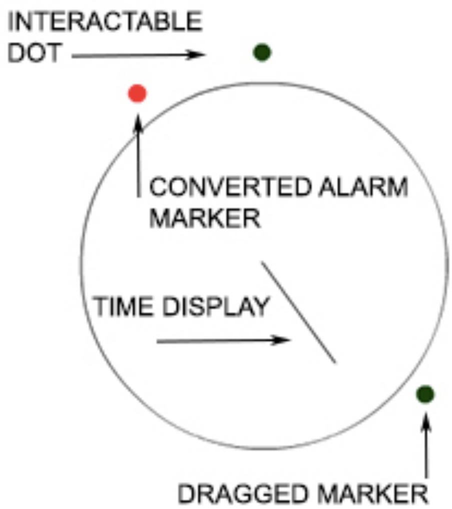

Fig. 3-2 Pomodoro application interactivity

3.3 Punctuality Application

When designing the punctuality application, we first divided time into two categories, personal time and shared time. When time is personal, the user has full control over all activities, whereas in shared time, the user must interact with other people or things. Time spent reading a book for example would be personal time, and a business meeting would be an example of shared time.

In shared time, time is used as a common reference point for all users. Because of this, it is important that all users use the same standardizations of timekeeping. However, in activities that involve only a single user, time becomes more flexible. Personal time can be manipulated and standardizations discarded, as long as during the next instance of shared time, the user is again using the same conventions are those they are sharing time with. The punctuality watch uses this concept to redesign timekeeping in personal time.

To correct the bad habit of lateness, many users set their watches ahead of the current time. Even if the user is aware their device is ahead, the visual cue of the watch hands nearing their deadline can still cause them to act. The punctuality clock improves this illusion by discarding the convention of seconds, minutes and hours altogether and measuring time at a new, customized speed.

The functionality of the lateness watch is illustrated in the following scenario. Two users, represented by the two applications, have an appointment to meet each other. The blue section of the applications represents a cycle of time, drawing from lessons in the range watch, this cycle is user defined. A line in the blue section rotates, marking the current time. Near the end of the cycle, the users have a black arc marking their meeting **Fig. 4-1**. In other words the black section marks shared time, and all else can be though of as personal time.

The left user is always on time, and therefor sets his watch to run normally. The right user however is prone to lateness and must make use of the application's extra functionality. We designed the application to run at variable speeds during a user's personal time. The application runs faster than a normal watch for most of the period before the meeting, meaning that before the meeting, a "second" on the right watch is actually shorter than the normal second, and time is compressed. This is illustrated in **Fig. 4-2** where after the same amount of time the right user's watch shows a later time than the left. The right user sees that it is almost time for the meeting and leaves at a time when, if the watch was normal, he/she would have been late. However, right before the meeting begins, time slows down on the right watch. A "second" becomes longer than the normal second, and the left watch catches up, until both watches arrive at the shared time point, the beginning of the meeting, together **Fig. 4-3**. Thereafter both watches run normally.

The application controls user behavior by redistributing personal time in a way that encourages punctuality. It is also aware that during shared time, all users must share the same standards of time.

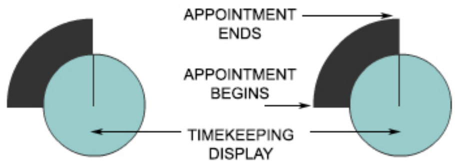

Fig. 4-1 Punctuality application on initialization

Fig. 4-2 Right watch counts time more quickly

Fig. 4-3 Both watches arrive at shared time in sync

4. Evaluation, limitations and future works

The scheduling application shows that if standards of viewing range and layout are discarded, it is possible to use zoom/pan functionality to collapse clocks and calendars into a single tool. This new tool allows users to view the current time in context of what has been done in the past and what is planned in the future. This application was made for computer screens and smartphones, however to make the tool truly cross platform, the interface should also be usable on future smart watches. The control and display panel interface used in the application takes too much screen real estate to be used in smart watch screens. For future iterations we aim to either further simplify the application UI or create an application specifically for smart watches. The data source options for the scheduling application are CSV or JSON files, however, for more usability the application should be able to receive information from applications that already house user scheduling information, such as Google Calendar.

The productivity applications allow users to divide time in the way they see fit, and easily create markers and alarms for their customized divisions. However, better UI design is needed to differentiate between multitasking related reminders and single task reminders. Additionally, the application performs very situation specific functions, and would be more useful if it became a feature built on top of a regularly used base watch, such as the scheduling application.

The punctuality application allows users to modify their own behavior by viewing time differently in their personal time. This application is also most useful if built as a feature on top of the scheduling application, as it requires information on the user's shared and personal time.

Finally the applications that were built using Flash should be rebuilt in a more generally compatible language, such as HTML, CSS and JavaScript, as Flash is not viewable on mobile platforms.

5. Conclusion

With the advance of technology, and especially the proliferation of mobile devices, many of our traditional tools are being redesigned. Though watches and calendars have been digitized, these and many other timekeeping tools still retain standardized configurations of their analog counterparts. With the power of today's digital platforms, there is more possibility in redesigning timekeeping tools to better suit user needs. By discarding conventions in viewing range, time divisions and time speed, applications for this project have showed that it is possible to replace current timekeeping tools with new interfaces and visualizations that put more control into the hands of the user. Challenges to the proposed design come from difficulty of creating usable cross platform, cross device interfaces. Future works will focus on this issue.

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