CubeLendar: Design of a Tangible Interactive Event Awareness Cube

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Abstract
CubeLendar is an interactive calendar in the form of a cube, which provides an overview of the events, weather, time, and date. It is a computer device that integrates an attractive design and exploits rotation as an interaction technique to access different types of information presented on each side of the cube. *CubeLendar* is aimed to notify about calendar events via light and represent potential situations for spontaneous communication with remote co-workers. Moreover, due to its appealing design *CubeLendar* nicely integrates into the office environment as a pleasant enhancement. In this paper, we outline the design concept of *CubeLendar*, hardware design, and first usability feedback. In our future research we aim to extend the feedback modalities for our *CubeLendar* prototype and build a network of such awareness devices to facilitate spontaneous communication in spatially distributed groups.

Author Keywords
Interactive calendar; Rotation-based interaction; Hardware design; Tangible interaction; Awareness display

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

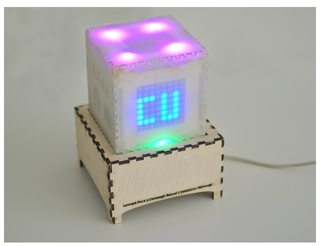

Figure 1: *CubeLendar*: sides D (top) and E (matrix display).

Introduction

In the office workflow, we often have to keep track of the meetings planned for the day. While working fully concentrated on the tasks we tend to forget and miss important events. In order to avoid such an issue we need an event awareness system.

One typical notification system is an electronic calendar with on-screen notifications [6]. Desktop pop-up application or smart phone reminders are also widely used as notifiers. However, this suddenly disrupts and leaves workers with unaccomplished tasks [1]. Another common strategy is to keep track of time till the next meeting by periodically glancing at the clock. In this case, the worker might lose the focus of the work which in turn may affect the productivity.

One solution for this issue is to shift the notification to the periphery of human vision. Systems such as AmbientTimer [12] and SpiraClock [7] work well as unobtrusive reminders about upcoming events using ambient light. They, however, do not go far beyond that and often pure notification provides a brief description about the event without specific details. We wish to know more about the event we are notified about, which leads us to the question: what is this notification about?

In this paper we present a tangible interactive cube that supports awareness of events and communication - *CubeLendar* (Figure 1). It is designed to provide unobtrusive reminders and notifications in the periphery of human vision using light as the presentation modality. *CubeLendar* exploits iconic information representation to display additional details about the events, such as place, time, or number of attendees in an interactive manner as if it was a dice. Due to its physical appearance *CubeLendar* maintains adding or retrieving information by simple tangible interaction with no need for a mobile phone or desktop application. Also due to its appealing design it nicely integrates into the working office environment.

Design and evaluation of *CubeLendar* as a calendar notifier is the first step in our work. In the ongoing phase of our work we aim to build a connected network of such cubes that will represent the presence of remote co-workers using ambient light, visual output on the displays and aural feedback, and provide methods for engagement into spontaneous communication. There are some approaches that use not only light as a medium for unobtrusive information presentation [19, 13, 21, 2], but also standard computer displays to provide implicit cues about the presence of a person [20]. Thus, we plan to turn *CubeLendar* into a "social window" that represents information about presence, activity, mood, etc. of the remote colleagues combining different modalities, which helps initiating a spontaneous communication between people under a distributed setting.

In this paper, we first describe the design concept of *CubeLendar*, provide a detailed overview of hardware and communication between software and hardware, and results of the first users' feedback. At the end, we give an overview of the future studies and implementation improvements.

Design Concept

Before implementing the form factor of the interactive cube we considered a number of geometrical shapes. Based on the previous work by Block et al. [3] we found out that a hexagon shape is interesting to explore , but its manipulation is rather unintuitive. Other shapes such as sphere [8] and cylinder are very playful, but they roll away after putting them down on a flat surface. Affordances of a cube were studied by Sherian et al. [15], suggesting possible requirements for the design of cube-shaped physical objects. Cube-shaped interfaces showed promising results being a

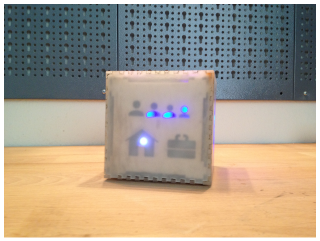

Figure 2: *CubeLendar*: side A - Work Details.

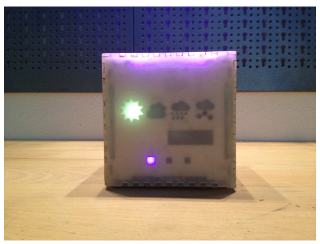

Figure 3: *CubeLendar*: side B - Weather forecast.

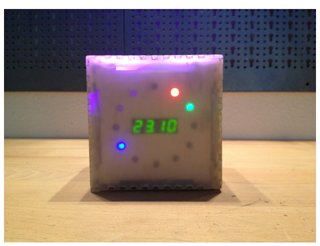

Figure 4: *CubeLendar*: side C - Time and Date.

navigation tool [4, 14], a remote control [3], and a learning platform for children [10, 18, 9]. For example, handheld cubic displays such as pCubee [16] and CAPTIVE [5] allow a user to interact with dynamic virtual scenes within the cube that react to display movement. Both pCubee and CAPTIVE can be easily held in one hand while using another input device, such as mouse or a 3D stylus. However, these prototypes support interaction with one virtual object within the cube, while each side of *CubeLendar* serves as a clear and separate display of information.

The shape of a cube can be easily handled by people and manipulations with it are intuitive: rotation, translation, and putting it down on the flat surface. For example, physical movements to operate the device in form of a cube were presented for Z-agon [11]. *CubeLendar* has different level of abstraction to represent information, such as ambient light, icons and textual information, while each side of Z-agon has LCD-displays. Thus, using all advantages of the cube-shaped interfaces we decided to build our tangible interactive calendar in the form of a cube (11 cm side).

CubeLendar has six sides (faces): work details (A), weather forecast (B), time and date (C), top (D), matrix display (E), and bottom speakers (F) (Figure 5). Additionally, the cube has two states that allow switching between the faces: *idle* and *standard*. The default state of *CubeLendar* is *idle*. In the *idle* state *CubeLendar* shows appointment unrelated information: current date, time, and weather data for a specified location. 15 minutes before an upcoming appointment all sides of *CubeLendar* switch to the *standard* state and show information related only to a certain appointment. After 15 minutes all sides of *CubeLendar* switch back to the *idle* state automatically.

Side A (Figure 2) indicates a number of participants in the meeting (one, two, three, and more) and another indicator shows whether it is a private (house icon) or business (suitcase icon) appointment. Side B (Figure 3) displays the weather data for the given time of the appointment. For this we used four main weather statuses: sunny, cloudy, rainy, snow and commonly used weather icons accordingly. As an indication of the day on which the meeting takes place the bottom area of this side uses three LEDs: today, tomorrow, day after tomorrow (from left to right). A user can switch between the days by rotating cube by 45° to the left or right similarly to sliding left and right on a smartphone. This rotation should last at least 1 sec. A user can also switch between appointments on a given day by turning *CubeLendar* up for previous and down for next appointment with the same angle and minimum duration of rotation as for day switching. Each selection shows the weather at 12 pm.

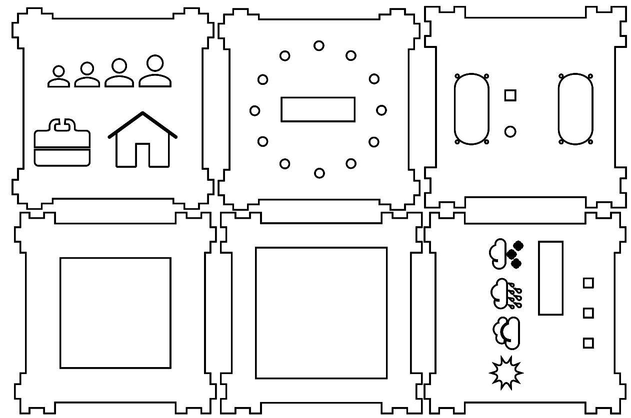

Figure 5: *CubeLendar* design. Top (from left to right): work details, time and date, bottom speakers. Bottom (from left to right): top, matrix display, weather forecast.

Side C (Figure 4) shows time using three different colors

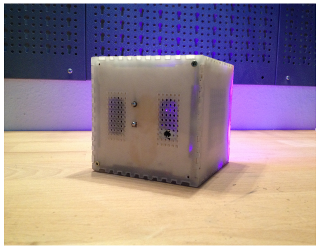

Figure 6: *CubeLendar*: side F - Bottom Speakers.

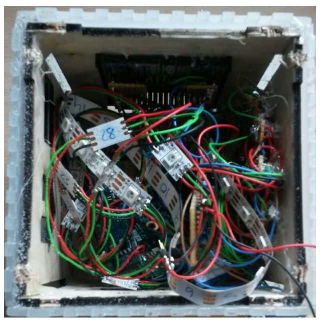

Figure 7: *CubeLendar* - Limited interior space.

1	1	1
1	0	1
1	1	1
1	0	1
1	0	1

Figure 8: Pattern for the letter `A`. The pattern is read row by row from upper left to lower right. The resulting sequence: `111101111101101`.

to indicate hours, minutes, and seconds. Date is shown in the middle of the display. The title of the appointment and other textual information is shown on the matrix side (Figure 1). The top side contains LEDs that indicate the type of the appointment according to the color from online calendar. Additionally, each edge of the cube has an integrated LED to give a user a hint about a direction it should be rotated to get additional information about the current displayed appointment. We also aimed to integrate a pair of speakers to the bottom part of the cube (Figure 6), but due to the power fluctuations we excluded them at this stage of the development.

Hardware Architecture

CubeLendar prototype hardware parts are organized as a fixed structure in a wooden cube which itself is enclosed by a semi-opaque Plexiglas® hull. The inner wooden cube serves as a mask for various icons that can be backlit with a set of Neopixels and thus be displayed on the outer hull.

All hardware parts are hidden from the software controller behind a layer of abstraction. This layer implements a specific driver application that provides a basic control protocol for each hardware component. A RaspberryPi serves as a main controller for software and hardware implementation. It also ensures programming language independence and additional memory. For easier prototyping we added an Arduino Nano and developed a control protocol on top of the I^2C protocol to send commands from the RaspberryPi to the Arduino board.

To enable interaction with the cube via rotation we decided to use a gyroscope module to process the orientation. To provide a distinct label for each face and edge of *CubeLendar* we used 18 labels - 1 label per edge or face. To determine the current label for a given dataset from the

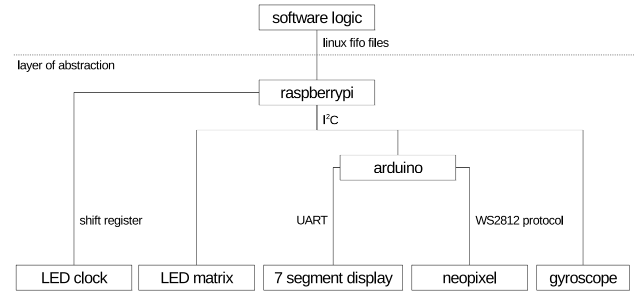

Figure 9: Overview of hardware components and communication protocols used in *CubeLendar*.

gyroscope, we used the supervised machine learning algorithm *K-nearest-neighbors* (KNN). For orientation sensing of *CubeLendar* we collected a set of 100 three dimensional data points from the gyroscope and took k = 20 for each label. After this training the algorithm can determine the label for any given data point by searching for the k nearest (using the Euclidean distance) neighbors in the training dataset with 100% accuracy. The most frequent label in the training data set is assigned. This technique is easily configurable and rather stable when determining the label for a given measurement. It also makes it very easy to reposition the gyroscope while constructing prototypes. This method uses the raw output from the gyroscope which makes it easier to replace the module with any other module with different output ranges without adjusting any formulas.

To display textual information, we used an eight by eight LED matrix with a HT16K33 controller that receives commands over I^2C from the RaspberryPi. Limited resolution of 64 pixels allows to scroll text only horizontally. All displayed characters are encoded in a 15-bit pattern that represents a three by five matrix. It indicates which LEDs to

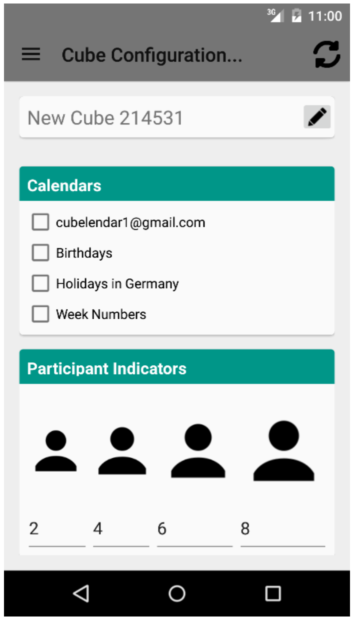

Figure 10: *CubeLendar* settings in the *Android Application*

turn on to display the desired character. An example for this encoding is given in Figure 8.

CubeLendar displays the current time through twelve RGB LEDs arranged in a form of circle as an analogue clock with a twelve hour clock face. To reduce the complexity of the control circuit, the LEDs are wired as a three by four matrix multiplexed by the RaspberryPi. A total of three matrices were used to control the color channels individually. Hours, minutes and seconds are displayed via different colors. Besides the LED clock face, we used a total of 31 Neopixels to control ambient lightning and highlight the various symbols. The Neopixels are controlled by the Arduino board which receives commands from the RaspberryPi. We used four digit seven segment display module controlled by the Arduino. We found that the *UART* protocol is the most stable way to control this module.

Software and Communication

CubeLendar receives new events from Google calendar using Wi-Fi connection. To setup a connection and change the settings of a cube we use the *Android application* (Figure 10). We let *CubeLendar* broadcast an own network and the *Android application* finds unconfigured cubes which need to be set up by matching the broadcasted SSID.

The *Android Application* establishes a socket connection to *CubeLendar* as long as they are in the same network. The socket communication is used to request a list of networks *CubeLendar* can be connected to. The user selects a network and enters the credentials if needed. Once the credentials are provided, *CubeLendar* stays in the network and can be reconfigured via the *Android application*. A user selects one of the found devices, chooses calendars from which information is taken and configure the behaviour of the LED-indicator lights. For our *CubeLendar* prototype we use *Google Calendar* service as far as it provides a framework to retrieve information from the calendar and allows to setup evaluation scenarios.

User Feedback

In order to receive users' feedback we recruited six students (2 female) aged between 20 and 27 (mean = 24) from a local University for a usability test of *CubeLendar*. Participants had to do two tasks: one with the *Android Application* and one with *CubeLendar*.

In the task with the *Android Application* participants had to modify all the settings on a specific cube. For example, they had to switch private or business appointment and observe an LED change. In the second task participants were asked to find an appointment and get information about its time, place and the weather. After both tasks participants also had to fill a questionnaire and were asked about the problems in a subsequent interview.

Based on the interviews with participants we identified three main implementation problems. The first one is a lack of indication between AM and PM time. The second problem is an unclear encoding of hours, minutes and seconds and distinction between them. The third one is an unintuitive interaction with a matrix side. Except that, *CubeLendar* received a very positive feedback about the form factor, design and interaction.

Conclusion & Future Work

We presented an ongoing work about the concept and technical details of interactive calendar - *CubeLendar* - as an event awareness device for a single user. With our early prototype we showed the design, the feasibility of the concept, hardware architecture and rotation as an interaction technique.

This work is the first step towards the future exploration of *CubeLendar* as a distributed shared calendar display, which will allow accessing the calendars of other colleagues. For instance, a worker with *CubeLendar* in his office will be able to access *CubeLendars* of his colleagues in order to know when and what kind of meetings they have, or even send an invitation or notification via rotation of the cube. Moreover, we will turn the existing top side (side D) and work details (side A) of the cube into the awareness side and represent environmental and social signals via light, such as presence at certain locations or type of social situation. Additionally, we aim to represent social activities and mood using other modalities or combinations of them. Thus, based on this early prototype, we aim to exploit a connected network of *CubeLendars* as awareness devices of other people's activities in order to evaluate different modalities and methods that represent them.

CubeLendar as the "bridge" between spatially distributed groups will also let us investigate new interaction methods for seamless transition between explicit and implicit communication. This part of effective social communication is an emerging field and has not been comprehensively studied [17, 20]. For example, after receiving information about the remote colleague by *CubeLendar*, the office worker can confirm the communication intent via rotation and initialize an explicit communication using already existing methods such video-conferencing, calling, etc.

We consider a distributed network of *CubeLendars* for the following use case: Two colleagues Mark and John have *CubeLendars* connected to work calendars of each other. Mark wants to discuss issues regarding the latest version of a product with John, but *CubeLendar* on Mark's desk indicates that John is having a meeting with partners in the conference hall at the moment. Thus, Mark takes *CubeLendar*, finds a free slot for a meeting in John's calendar and sends him an invitation for a video chat. When an invitation is sent, *CubeLendar* on John's desk implicitly indicates about Mark's will to communicate. John can accept Mark's invitation for a suggested video chat by interacting with *CubeLendar* via rotation.

We intend to evaluate *CubeLendars* in spatially distributed settings with the following research questions:(1) How do we represent implicit cues expressing the possibility to interact with remote persons? (2) What are appropriate methods to transit from implicit to explicit communication, and vice versa? (3) Which methods can we use to enable appropriate interaction on an explicit level? (4) What is the impact of the developed concepts on the social behavior of distributed work group collaboration?

For the technical side we plan to add audio as an additional notification modality. The audio output can be used to grab users' attention, when *CubeLendar* is out of sight. We also aim to improve the clock face, which could be changed to a set of Neopixels instead of ordinary LEDs. This will eliminate flickering, which occurs when *CubeLendar* performs computationally intense tasks. With our prototype we also prove that a cube-shaped notification system can provide an easy and intuitive interaction, and can be nicely integrated into the office working environment.

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