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SMART DISPLAYS: PERSONALISATION OF INFORMATION PANELS

Ivo Pisařovic[1], Tomáš Koubek[1], Vít Ondroušek[1], David Procházka[1]

[1]Department of Informatics, Faculty of Business and Economics, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic

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Abstract

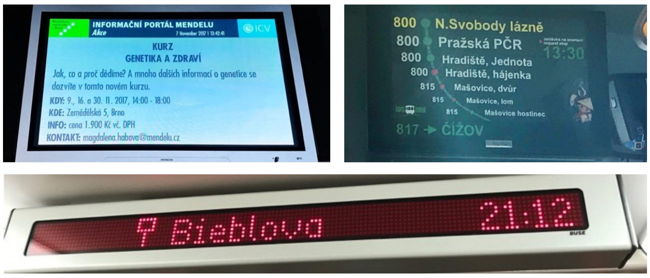
Information panels are a common part of university or administrative buildings. We can see large panels with news or social media feeds as well as small displays on conference rooms with information about their occupancy. All these panels usually present general information without any relation to a present audience. Presentation of personalised information for a particular user can be very helpful; however, for such personalisation we must take into account many aspects: identification of users in the display vicinity, sharing of the screen among multiple users etc. This paper is focused on the architecture of such system that allows presenting customised information on information panels for users within university buildings. Our solution allows detection of a user via Bluetooth beacons. The selected close display then presents information related to the user. In case there are multiple users in the display vicinity, the system evaluates their requirements and decides how to share the display.

Keywords: information panel, smart university, smart city, Bluetooth beacons, personalisation, location-based service, user interface

INTRODUCTION

Common displays show information that is not directly related to users in the display vicinity. Obviously, this is quite wasting of display potential because the displayed content is often uninteresting for the people and, therefore, the display is ignored at all. Examples of such displays are in Fig. 1. On the left-top image, we can see a display with an invitation for a genetic course. However, genetics is interesting only for a limited group of people. For others, this information is not useful. On the right-top image, we can see a display in a bus displaying bus stops, the final stop, time etc. You can mention that on both displays there is a lot of small texts. New users can be easily confused with the excess of information. In the case of the bus, it is even not completely clear what is the current stop, what is the final destination etc. Compare it with the bottom image taken in a different bus where one simple line provides all important information in a much more readable way even from a far distance. Moreover, it cannot be confusing even for new users.

Smart display response to the needs of surrounding users. They are a natural part of a smart environment and put a low cognitive load on the users. We can take a real example: compare the comfort of taking a mobile phone and searching for traffic departures to looking on a large display with a list of nearest departures. Obviously, the second case is much more comfortable and natural. Smart displays create a connection between real world and digital information. It makes interaction with common technical equipment much more natural. Nonetheless, there is no unique



1: *Examples of displays with general information. Image credits: MENDELU, IDS JMK.*

definition of a smart display. In fact, there is even no strict delineation between common and "smart" display. The transition is fluent from completely general information to precisely personalised for particular user. Let us take an example. General information panel can display regular departures from a bus station. "Smarter" display can receive real-time information about delays of the busses on the road. An even more personalized solution can display specific information about nearest departure of the bus you need in the particular moment. Obviously, it is about point-of-view, when we are able to call some solution a smart display.

Students spend much time on a university campus. During this period, they solve many different problems and administrative tasks. Freshman students face the problem with orientation in large buildings, advanced students solve many problems with their final thesis etc. Furthermore, the study department is frequently crowded with people in the beginning of a semester. Despite that, most of the students ask the same things. Therefore, we focus in this paper on the design of a smart display system that can help students to solve their common problems. These problems are almost exclusively study related. They have been identified on the basis of the interview with freshman and more experienced students as well as with the faculty study department.

Review

Location Services

The key instrument for providing user-related content is a location service (also called location-based service). Knowledge of user location is necessary for identification of users that are present in the display vicinity. The formal definition of a location-based service, as well as a review of many technical aspects, can be found e.g. in well-known book Location Based Services (Schiller, J., Voisard, A., 2004). Technical issues of the indoor positioning are described in-depth in Indoor Location-Based Services (Werner, M., 2014).

Currently, there are many projects focused on providing location-aware content on the basis of user location. Examples include:

- Sending sale coupons to mobile phones when a user reaches an area of interest. E.g. stores Tesco Lotus or Hamad International Airport (Tesco Lotus, 2018; Passenger Self Service, 2016).
- Recommendation of food recipes on the basis of user preferences and time. E.g. Marc's stores in Ohio (Mittal, 2016).
- Obtaining information with regard to the time, visit length and location for museum visitors. E.g. Guggenheim Museum in New York or Los Angeles Zoo (Anderson, 2017).
- Delivering content to specific parts of a stadium: Camp Nou FC Barcelona (Duque, 2015).
- Location based to-do list: Proximitask (Mallik, 2015) or Google Keep.

Location-awareness and generally context-awareness are important for simplifying the user interfaces. However, we must consider that frequently changing user interface makes it less memorable and the cognitive load rises in case information is not served well. (Feng a Liu, 2015)

Beside the user location, it is also useful to obtain information about user behaviour. Liu, Wu a Wang (2014) described a solution for recommending activities based on user movement and place of interests.

Hörold, Mayas a Krömker (2015) described the positioning of such displays in public traffic. A wrong position can make the display unreadable due to an uncomfortable point of view, far distance or obstacles in the way of sight, like other passengers.

There are several methods for precise indoor localization. Frequently used is localization via Wi-Fi network signal (Martin *et al.*, 2010; Li *et al.*, 2017). Interesting is the usage of acoustic waves (Ali, Javed, Hassanein and Oteafy, 2016). Probably the most popular localization technology nowadays is *iBeacon*, a simple small device with a Bluetooth antenna transmitting an identification information. These devices are so popular thanks to easy installation, fast configuration and low costs. *iBeacons* are not aimed at precise localization but perform well as proximity sensors. (Zafari, Papapanagiotou, Devetsikiotis a Hacker, 2017).

User Interface

To design display user interface, it is necessary to follow basic principles of user interfaces (Nielsen, 1995; Tidwell, 2011; Hoober a Berkman, 2012; Cooper, 2014; Mortensen, 2017). Following design principles are applied to our display user interface.

- Abstraction. Before designing user interface basic user needs must be defined. In this definition, maximum reduction of details must be made. The right identification of user needs allows to minimalize worthless display content and makes the displays more efficient by displaying only the most important information with a low cognitive load.
- State visibility. The users must be aware of the context of displayed content. For example, when displaying info about a conference, the context is the conference. The context can be expressed as a header above the content and it must be consistent across different views.
- Match with reality. This helps users to orientate in the user interface easily.
- Consistency and habits. Users have a domain knowledge and use a domain language. The display should speak in the user language. The display should display content consistently according to user expectations.
- Graduating user skills. Respect different point of view of users at different levels. A new user: "What can I do here?", intermediate: "Where can I find building X?", expert: "Can I automate this?".
- Clues. The display space is limited and not all the contents can be displayed. Clues can be used for noticing users about the possibility of showing more content or performing an interaction via mobile devices.

In our case, we design user interface for two different types of displays – small e-ink displays positioned at classrooms and large colourful displays at entrances and corridors.

MATERIALS AND METHODS

Function Specification

Based on analysis of user needs, as mentioned in the Introduction, we designed six general functions of the proposed system:

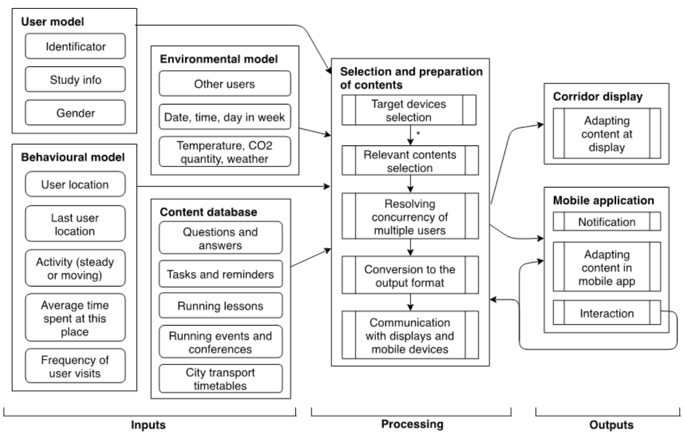
1. Pass a primary content to a user. A primary content is, for example, an exam term, a solution of a study duty, a list of running lessons, a conference program or a security warning.
2. Pass more information about a primary content to a user on demand. E.g. if the primary content is conference welcome, the more content can be a detailed conference program.
3. Allow a user to interact with the content. The interaction can be for example a comment or a "like".
4. Allow a user to take an action related to the displayed content. E.g. switch to navigation for navigating to another building where a conference reception takes part.
5. Allow a user to save provided content for later time.
6. Notify a user about a primary content based on his or her location or time. Allow a user to add a custom notification.

Such functions are completely general and can be implemented for any similar system (e.g. even a system for municipal authority).

Smart Display System Model

To fulfil described tasks, we proposed a system with several inputs, inner logic, and outputs as you can see in Fig. 2. Similarly to the function specification, this model is completely general and can be possibly extended. We used some objects that are specific for the university environment in the model (e.g. running lessons); however, this information can be replaced by any information from the target field. We find such straightforward.

Inputs in the model include information about a user and user behaviour and also information about the environment. Study information includes the user's current semester, a field of study, user's timetable etc. Certainly, any implementation can work just with a subset of the functions described in the model. For instance, to preserve user privacy, many systems would not implement identification of the particular user, his/her activity etc.



2: *Model of the system that is able to provide content on the basis of different inputs.*

Content Adaptation

As you can see in the middle part of Fig. 2, the content adaptation consists of five steps. All these steps are performed on a central server that is an intermediary between user devices and displays.

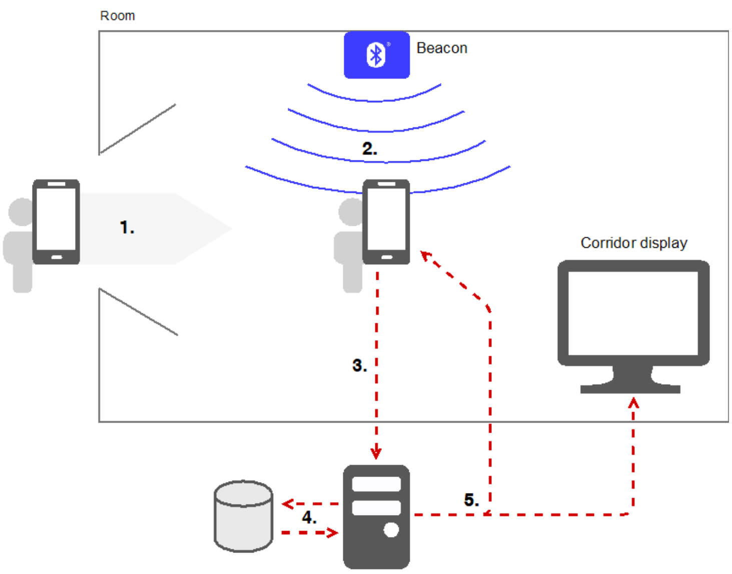
1. Target device selection. All displays must be updated periodically. However, in case of an urgent action (user changes location fast), a display that is closest to the user can be updated immediately.
2. Relevant content selection. Each content in the database can be attached to a user model, a user behaviour model and an environment model. While selecting relevant contents current models are compared to models attached to the content in the database.
3. Resolving user concurrency. If there are multiple users in the display vicinity with different needs, the content is chosen according to following rules.
   a) If the content is marked as *parallel*, multiple information (content) are displayed at once on the display.
   b) Otherwise, the contents are ordered by the content *priority* value. This value can be furthermore raised based on the count of users matching the content parameters. Only the content with the highest priority is displayed.
   c) In case there are multiple contents with the same *priority* value, the content can be chosen randomly.
4. Conversion to the output format. Public displays have different ways of receiving content. Therefore, for each type of content, must be prepared several templates to allow displaying the same content at different resolutions, colours etc. The output will probably include:
   a) A large web template for large displays at corridors.
   b) A mobile web template for displaying content in mobile devices.
   c) A small raster template for greyscale e-ink (or colour TFT LCD) displays in front of doors.

We efficient can be to render a raster image on the server side that can be displayed by virtually any device.

5. Communication with displays. In the final phase, the content is sent to displays via push notifications or using display selected interface. Very popular is e.g. the REST standard for such communication.

User Localization

Each mobile platform has particular tools for device localization. For instance, for localization of mobile devices in open spaces on Apple platform, we can use Apple's Core Location framework (Aplle, 2017b). This framework combines different methods for obtaining precise user location (Wi-Fi, GPS, Bluetooth, mobile networks). Thanks to so-called crowd-sourcing the position is quite precise, however not enough to localize users around a display indoors (Apple, 2017a). This kind of location can be used for determining that the user reached a university campus, but for further interaction with displays is necessary to use another method of localization, e.g. a local positioning system.



3: *The process of identification of a user with a mobile device in the display vicinity and adapting the display content according to the user needs: A user enters the target area (1), e.g. corridor before a classroom. Beacon send a token (2) that is received by the device and send to the server with anonymous user token (3). The server identifies the location and the user on the basis of the tokens (4) and sends content to the corridor display and the mobile device (5).*

To obtain location data that are the main input of the system, we can use iBeacons and mobile devices. The whole process is shown in Fig. 3. The blue colour indicates Bluetooth signal from an iBeacon. Red arrows stand for communication among devices. 1. A user enters the room. 2. The signal from iBeacon is received by the user's mobile device. 3. The mobile device sends user information and location to the server. 4. The server selects relevant contents as described in chapter Content Adaptation. 5. Selected content is displayed on the display or in the user's mobile device.

Interaction

Generally, there are the options for interaction with the display. The first one, and most common, is to use a touchscreen. Advantages are obvious. However, for large public displays is such technology frequently inconvenient. The size or position of the display can make the interaction difficult or even impossible. The second common approach is the use of some buttons usually placed on the rim of the display. The indirect interaction can be even harder from the usability point of view and similarly to the touch screen the position or size of the screen can make such control unsuitable.

Therefore, we propose that additional content can be displayed on a user mobile device. A clue must be present on the display to show the possibility of using the related mobile application. Via this application user can interact with content too. The interaction options are saved in the database along with contents in form of links to web pages or links to other mobile applications. Such interaction can be completely private and can be used with any size of the display. The only obvious disadvantage is the necessity to have a compatible mobile application. Therefore this function should be implemented into an application that is part of the institution ecosystem (e.g. mobile information system of the institution).

RESULTS

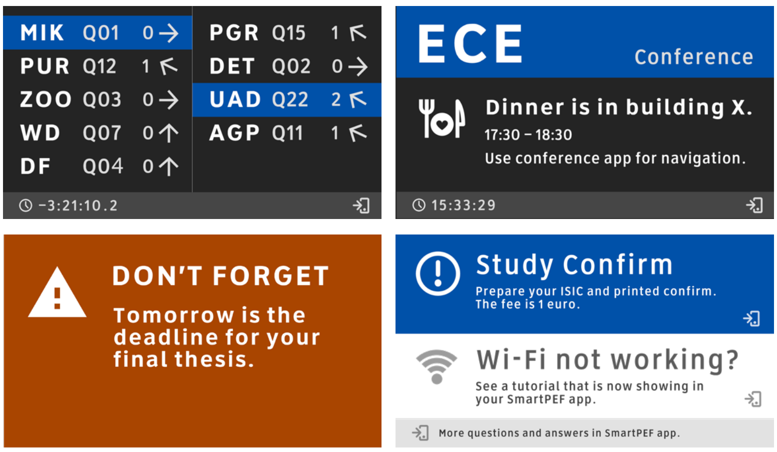
User Interface

We followed common rules of user interface design described above. While designing, we were inspired by departure panels that can be seen at airports and by common traffic signs at roads. Based on a conversation (Meta Filler Network, 2108) we chose font Roadgeek (Adams, 2005) that is similar to the font used on common road signs. This font excels when reading from a far distance. We used a black contrast background with white texts for the best readability and we tried to minimize graphical elements. Examples of our designed interfaces are in Fig. 4. The left-top image shows a list of lessons starting in 3 minutes. A lesson name, a room name, a floor number and a direction are displayed for each lesson. Moreover, the blue background is used to highlight lessons for users that recently entered the vicinity of the display. The right-top image shows information about dinner when it detects a user with the conference app. Users can use the mobile app for navigation to the building X. The left-bottom image shows a notification when a student of the last semester is near the display. The right-bottom image displays questions and answers relevant to surrounding users. This display is located in the study department. You can see a little icon in the bottom-right corner of the screens that is a clue indicating interaction possibilities via mobile devices.

We also designed user interface for displaying the contents on the user mobile devices and for interaction with the contents. The design of the mobile application will be published as a separate paper.

Implementation

Currently, we have successfully implemented a prototype. It includes a mobile application for gathering user information and displaying contents, a server for selecting relevant contents and display applications for two types of displays.



4: *The design of user interface for several common displays.*

The whole system is composed of many internally simple and independent components. Thanks to this approach it will be very easy to maintain such system in the future even for developers without previous skills.

Mobile application is implemented for iOS platform using Swift version 4.0 and Xcode development environment. We used library SnapKit[1] for creating user interface out of storyboards that are not suitable for development of large applications with many developers and complicated UI elements. For synchronization of data with the server, we used AFNetworking[2] framework.

Server is implemented using Node.js together with an in-memory document database called LokiJS[3]. These technologies allow the server to respond very quickly that is necessary for updating contents on the display immediately after a user enters the range of an iBeacon.

Display applications for larger colourful displays are simple web pages. These applications are responsive to adapt to different resolutions and sizes of displays. Contents to these displays are sent via push notifications from the server.

The application for smaller e-ink displays is written in Python. It runs on Raspberry Pi 3 connected to the display. Content in form of a PNG for a display is sent via REST interface of the Python application.

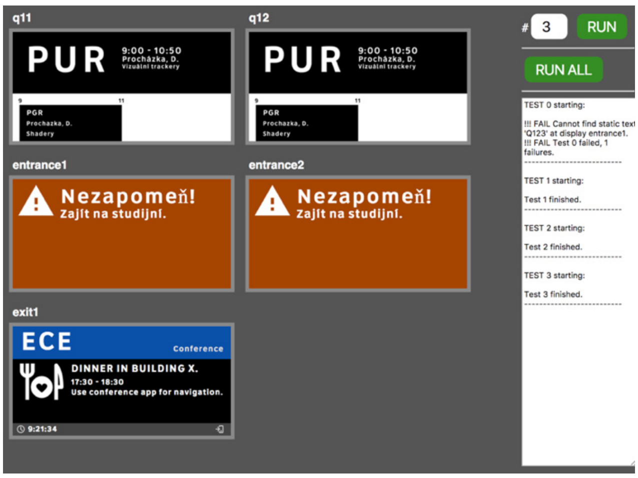
To test the whole solution, we also implemented a custom web-based tester that is performing end-to-end testing of the server and display applications (see Fig. 5).

DISCUSSION

The key merit of our work is the methodology of a smart display ecosystem design within virtually any larger organization or institution. We dare to argue that principles described in section Function Specification should be fulfilled by any implementation of the system. Further, the presented architecture provides a platform for their fulfilment.

We proved our design using the described prototype of the smart display system. The implemented prototype was tested in our laboratory. Results from this testing were used to perform little modifications to the system, e.g. it was found that it is not possible to detect whether a user is running or walking because it is very subjective. Therefore, we detect furthermore only two types of user activity: steady and moving. Moreover, we made several modifications of the content structure (format of a time, the position of the elements etc.) to make the content more understandable. During the testing, the users were able to understand all the presented information; nonetheless mentioned changes allows them to get the right information in a shorter time span.

Our future work will be aimed on design of more content templates for other specific situations. Moreover, an online content management system must be developed to provide access to data also for non-technical users like study department workers. Deployment of our system is planned to the end of year. Certainly, there will be some modifications after the deployment; however, the main core of the system works fine as has been proved during testing.



5: *Fig. 5 Web-based tester of displays. For each predefined test, it passes test data and test environment including fake users to the server. Then it waits till all the displays are refreshed. Finally, it checks whether emulated displays contain the expected texts.*

1 http://snapkit.io/
2 https://github.com/AFNetworking/AFNetworking
3 http://lokijs.org/

CONCLUSION

The system of interconnected displays is able to deliver actual information precisely, e.g. count of unoccupied computers in a classroom or current schedule. Furthermore, the key advantage of this system is its ability to interact with the users. The content of displays is based on the activity of users in the vicinity. To reach the maximum potential of the displays, users must be aware of possibilities of their mobile devices and they must have Bluetooth turned on.

We assume the role of these displays will become more important in near future. The smart displays could significantly change the present way of communication among staff, students and outsiders, even though the input and maintenance costs are not negligible.

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Contact information

Ivo Pisařovic: xpisarov@mendelu.cz
Tomáš Koubek: tomas.koubek@mendelu.cz
Vít Ondroušek: vit.ondrousek@mendelu.cz
David Procházka: david.prochazka@mendelu.cz