# PERSONALISED DISPLAYS

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## ABSTRACT

This project is an exploration on personalization in public displays based on the idea of bulletin boards. We designed a system which provides the same functionality as bulletin boards do but in a smart way using public displays. The system takes advantage of new technologies and environments to make bulletin boards smart. It recognizes users of the system that pass by and personalizes the content of the display according to the users' preferences which they set up on their phones. It also takes into account several users around. We also explore the possibility of recognizing who is the user closest to the public display to try to determine who is using the display at any current moment, and we give solutions as to how to make this possible. Furthermore, it's a vision of how public displays can be used for something else than advertisements.

## Keywords

Public displays, Smart bulletin boards, HCI, Personalisation

## 1. INTRODUCTION

Public displays are starting to become more popular every day, but they still have a low interaction rate with the potential users. Most of its use is based on advertisement, which, although it's a revenue for the owner of the display, doesn't provide all that it could to its potential consumers. This types of public spaces are very powerful since they give interactivity and dynamic functionalities to people around it, but the downside is either that the information shown is very generic so that it's useful for everyone that approaches, or it displays too much data so that anyone can find the information they want. This situation limits the richness of the interaction as well as the possible uses of a public display.

**Figure 1. Bulletin board on the Infinite Corridor at MIT (2004) [31].**

Our purpose with this project is to provide more relevant information in public displays through automatic personalization of the content is shows by leveraging the fact that most users carry a smartphone with internet connectivity at all times. This will be achieved by mimicking a bulletin board and transforming it into its digital version which is not only smart but interactive and dynamic. By being digital, more organized layouts could exist compared to the current ones seen on Figure 1 and 2 and much more data could be displayed at the appropriate time while consuming less physical space. The organization is key, since bulletin boards have a big flaw which is that finding content on them is hard. Updates are not as frequent and certainly less visible when they happen, since changing one of the posters doesn't immediately trigger a response from the user.

**Figure 2. A bulletin board from a Starbucks [32].**

With this, we would like to find if users are more likely to interact in public spaces if the content is tailored for them when they approach as well as the pros or cons the digital counterpart of a bulletin has versus it. This also gives us the opportunity to explore personalization for groups instead of individuals, as well as study how much information are consumers willing to give in exchange of more tailored information.

## 2. RELATED WORK

Nowadays, public displays are more and more prevalent in public spaces [42], but a lack of useful ways of interaction exists. Most of the content found in public displays is "almost entirely of non-interactive vertical displays consisting of announcements for services, events, resources, "fun facts," or products, as well as more abstract artistic content" [43]. Not only this, but people have gotten accustomed to them and hence, this displays have become invisible [44]. Several attempts have been made to improve the user experience on them, like studies of the whole interaction between the potential users and the display, stated by [45], where they studied the interaction phase of user from passing by to a subtle interaction, classified as attention and direct interaction and multiple interaction classified as motivation, and how each of this phases should be tackled differently to enhance the user experience. Furthermore, they argued that public displays need a balance between capturing attention from people interested, and not annoying people who aren't, as well as enable people to maintain a coherent role in the public.

With this in mind, many studies towards improving the user experience as well as the benefits of this type of interaction have been done. For example, an application to increase civic engagement on young population was done, where public displays were used as a channel of communication with the local government as well as an entertaining activity [46]. Other type of approaches have dealt with crowdsourcing problems for situated public displays, like queue estimations of restaurants by users that can then be used by others in different locations to display useful information about the queue on a potential destination restaurant [47]. This system also merged the use of mobile phones as potential windows to the information gathered by others. With it, they managed to reduce unoccupied time and create a better waiting experience for their users.

Other types of applications have emerged from the idea of personalising displays, this time not using the smartphones just as a viewing window into the collected data, but as a real interaction with the displays. Personalisation of content has been done leveraging the use of Bluetooth from users' smartphones. In [48], they used the device's Bluetooth name to personalise content in public displays. With it they showed information like maps, pictures, YouTube videos, Google search results, generic web addresses and music. Other systems like Tacita [49], focus on the architecture by tackle many problems of personalising displays, specially privacy and security. They are built to avoid open communication from the phone towards the public displays, and instead the phone recognises a display in the vicinity and then starts personalising, in this way avoiding just broadcasting the content.

Except for the mentioned applications of using smart phones, wearable devices have also been considered as a way of personalise in public displays. One project [50] has the advantage of using wearable devices to broadcast user's interest into environment and the other [51] installed RFID tags into public displays and through today-worn RFID tags to read users profiles.

Digging deeper on personalising public displays, different levels of personalisation have been recognised as [52] shows. First, personalised information that must not be shown in the public. Second personalised information that can be shown in the public, and finally personalised information that can be shown in the public if no direct link exists to the source.

Looking closer to the topic at hand, bulletin boards have been studied and tried to be replaced by public displays. This has been passively happening as advertisements fill this public spaces, which before were in posters, but closer approaches exist. Context aware public displays were created as an addition to the paper based notice boards in [53]. They analysed the use of the paper based equivalent and classified posters in actionable and non-actionable ones. The actionable posters had deadlines, like exams, while the non-actionable didn't, like snippets of news. With this in mind they created two systems, a news display for actionable information, which is not context aware and is just shown as they are created, and a reminder display that show actionable posters at opportune moments depending on the location and the time the display was situated. With this study, they found out that the update rate of information is extremely important, as well as the balance of how much actionable posters versus non-actionable posters were shown. And finally they found out that the displays should be placed in entrances so that users at least have to see them twice, and in waiting areas to maximise viewing time.

Our system takes both worlds, both context aware public displays, which display content appropriate to the time and place where they are, but shows personalised content that is of interest of the passer-by's, and in this way it can provide useful information for everyone.

# 3. SYSTEM

Our system is centered on public displays. The public displays show content that would normally appear on bulletin boards, divided in four categories, jobs, events, adverts and courses (Courses was selected since our testing environment was a university). This content is personalized depending on the people surrounding the public display. A device on the public display detects mobile devices of users who have our app installed with their preferences and changes the content of the display. Moreover, the user can send information from the public display to their smartphone by tapping the content they want.

## 3.1 Implementation subheading

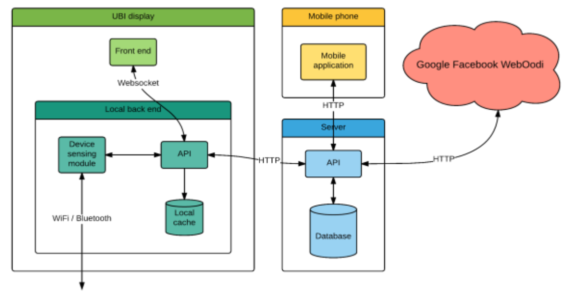


**Figure 3. Three tier system design.**

At this state design of this system consists of three major components which can be divided into smaller subsystems as displayed in Figure 3. These major parts are UBI display, mobile phone and server.

## 3.2 UBI display

The largest subsystem is the UBI display component which contains front end and local back end. Front end will be build using html, javascript and css and it communicates with local back end through socket.io websocket library. Depending on access level on UBI display the static front end files will be served with Nginx or Apache web server. Local backend will be built with golang which allows fast and easy deployment with static binary files and offers great variety of libraries for multiple use cases with build in concurrency patterns. Back end will contain three components device sensing module, local cache and API module. Device sensing module will use Bluetooth and Wi-Fi interfaces to detect passing devices. To make this possible we will use airmon-ng which turns Wi-Fi interface in monitor mode and allows us to detect mac addresses of passing devices. For Bluetooth sensing we will use PayPal's gatt library for golang. Local cache will contain data that needs to accessible within milliseconds to personalize data on display for passing users. At first this will be stored as map of structs in application's memory but can be converted to Redis in-memory data storage if needed. API module will serve as connection point for all modules in UBI display and as a gateway to main server. For websocket connection we will use go-socket.io framework and gorilla's mux library for the http connections.

## 3.3 Main server

The main server will contain two main components; database and API module. For the database we will use PostgreSQL and the API will be built with golang. API acts as a connection point for UBI displays, mobile clients and external data sources. Through this API module the data will be synchronized between data sources and PostgreSQL database.

## 3.4 Mobile application

Mobile application will be native Android application build with android-sdk. This mobile client will communicate with API over http and also receive push notifications from cloud. For push notification we will most likely use Google's cloud platform which allows us to send notifications and easily capture those on mobile device.

# 4. EVALUATION

We did two evaluations, one for the system's performance and one for the system's usability.

## 4.1 System evaluation Procedure

Using predictive evaluation, we identified the common uses of a typical user and hence identified the possible weaknesses of our system. The first possible weakness was if the user would be recognized when he walks by the public display. Secondly we would test if the public display was capable of identifying which user was the closest to the display if more than one user was present.

### *4.1.1 User Detection*

To test if the user would be recognized when he walked past the public display we decided to make a two-fold test. First we tested the speed of personalisation and then we measured the maximum distance of personalization. To test the speed of personalisation we placed a mobile device registered with our system at a two meters' distance from the public display and measured the time span between turning the Wi-Fi sensor on and seeing the content personalised on the screen. For this to work we first registered the device and subscribed it to several topics so that we would acknowledge when the content was personalised.

This was done at a two meters' distance arbitrarily since the Wi-Fi speeds are extremely faster than our system's detection, so the difference of speed between close distances and long distances is negligible. To have an accurate time we tested this process 20 times.

For the maximum distance we turned of Wi-Fi on the mobile device at a 10 meters' distance and waited to see if our sensing device detected it. If it did, we turned Wi-Fi off, waited for our device to stop sensing it, moved 10 meters away and turned Wi-Fi back on. We iterated this procedure until either the device wasn't sensed anymore. Figure 4 shows the setup for this experiment.

**Figure 3. Maximum distance setup**

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Personalised Public Displays

University of Oulu

### *4.1.2 User Proximity Detection*

To test if we could identify which was the closest user we decided to make a heat map of signal strength around the public display since this is the measurement our system uses to determine the closet user. To do this, we took measurements at a 1 meter' interval distance starting at 1 meter in front of the display. We turned on the Wi-Fi on the mobile device used and leave it still for 1 minute, then moved it 1 meter and waited again for 1 minute until we went to 8 meters. Then we did it again to one of the sides of the public display, assuming both sides would have the same results. Figure 5 shows the setup for front and side.

**Figure 4. Signal strength experiment setup**

### *4.1.3 Environment*

The test was carried out on a lab room. The sensing device was an Andriod device with Aircrack-ng, a network software to sniff Wi-Fi packets. Since this is not supported natively by Android, a custom kernel developed by Ruby Feinstein and Omri Ildis [11] [12] was used. This kernel only works on WiFi Chipsets BCM4329 and BCM4330. Because of this, a Nexus 7 (2012) which has Chipset BCM4330B2 was used. The OS on it was Cyanogen 10.1 and it was rooted to be able to access the monitor mode features. This sensing device was placed on the bottom of the display near ground level.

The public display was connected to a Mac Mini and was using Chrome version 49.0.2623.87 (64-bit). It was connected to the internet through the wireless network PanOulu.

The mobile device used for all the testing was a Samsung Galaxy S4 mini.

## 4.2 Expected outcome

### *4.2.1 User Detection*

We expected to have an average below 20 seconds to personalise the display from the moment the mobile device was turned on since we were scanning every 10 seconds and the communication going from the sensing device, to the server and back to the public display should take more than 10 extra seconds. We assumed it would take longer than 10 seconds since the mobile phone takes some time to start sending broadcasts with its mac address.

For the maximum distance we were expecting the values that an average router advertises as the maximum coverage which is around 46 meters indoors.

### *4.2.2 User Proximity Detection*

In this experiment we were expecting to have many areas in which we had false positives because of our experience with the system from beforehand, but we had to test it appropriately to make sure.

## 4.3 User evaluation Procedure

For the user evaluation we took features of field studies as well as task-based evaluation. During the evaluation, the think-aloud protocol was used.

### *4.3.1 Test Procedure and Environment*

The evaluation process was carried out with one participant at a time. During the evaluation process, we provided as few instructions on how to interact with the system as possible until the very last stage or until the user was badly lost. This was done so that we could associate this result with people's behaviour in the wild environment. Our participants were at first shown to the public display and allowed to explore as they wish. In this way we would expect to observe how users may figure out the usage of the system as well as turning it into a metric that measures usability of user interface in general. We also asked the users to find some information on the public display so that they would see what the contents were. Then we moved on to the mobile application and once again let participants play around with it. Then we brought them back to the display however this time, the difference was having two systems together to interact. After some time passed we gave them a couple of tasks to perform. At around this point participants would have had noticed how the system works, in general. At the end of the evaluation, we did some Q&A, provided the exact idea of the system and how it works, and the entire process was ended by feedback and a second Q&A.

### *4.3.2 Participants*

| Age group | Gender | Profession/ occupational Background | Past usage in public display | Activeness in joining public events |
|---|---|---|---|---|
| 21~25 | Male | Student / Computer Science | Checking traffic information | Almost none (2~3 times per year) |
| 21~25 | Male | Student / Computer Science | Entertainme nt application (selfie app) | Almost none (once in many months) |
| 21~25 | Male | Student / Computer Science | Checking nearby services | Almost none (2~3 times per year) |

**Table 1. Participants basic information**

During the evaluation phase we collected 3 participants in total. Table 1 lists the basic information of them which could help us build assumptions on the behaviours of the participants while interacting with the system. First thing to take a look at is commonality. We have three subjects with similar background, this can be noted as one of the limitations of the result of this evaluation. However more likely, these kind of evaluation settings may provide better qualitative feedback in technical related matters.

## 4.4 System Evaluation Results

Regarding the user detection, we collected 20 samples which in average resulted in a 28.6 seconds time to detect from the moment the Wi-Fi sensor of the mobile device is turned on, and a standard deviation of 5.616. The confidence interval of 95% is (25.6,31.3), which means it takes in maximum 31.3 seconds to detect the user once his Wi-Fi is turned on. The maximum distance was much more than expected, the maximum distance at which we could detect the device was 90 meters. We couldn't test in a longer distance since this was the longest distance indoors we had.

With this results we can assure that any user will see personalized content when he reaches the display, since assuming a normal walk speed of 5 kilometres per hour, traveling 80 meters would take almost 2 minutes (111 seconds). Even at twice the speed it would be the equivalent of 1 minute to reach a radius of 10 meters around the display, and it will be personalised within 30 seconds of detection of the device which happens from more than 90 meters away.

For the user proximity detection, we got 5 or more results for each scenario and first made T-tests to compare the means between the results of the measurements done in front of the screen and the side of the screen. The p-value was 0.3902, which means the means are not different and our initial assumption was true in a global scale. We then tested within groups by splitting the data by the distance from the sensing device. The results obtained are in table 2.

| Meters | P-value |
|---|---|
| 1 | 0.1607 |
| 2 | 0.1632 |
| 3 | 0.08525 |
| 4 | 0.00001982 |
| 5 | 0.04025 |
| 6 | 0.5911 |
| 7 | 0.0009098 |
| 8 | 0.07854 |

**Table 2. Statistic results of t-test tests between side and front**

To view this data properly, we merged the values from the meter's distance that weren't significantly different, as these regions behaved similarly, and then created a heat map using green as 0 RSSI and red -100 RSSI visible in figure 6. FIgure 7 contains the same heat map in a more interpretable scale. The numeric results are also available in table 3.

<table>
<tr><th>Meters</th><th>Front</th><th>Side</th></tr>
<tr><td>1</td><td colspan="2">-35.5</td></tr>
<tr><td>2</td><td colspan="2">-38.7</td></tr>
<tr><td>3</td><td colspan="2">-41.8</td></tr>
<tr><td>4</td><td>-40.3</td><td>-47.7</td></tr>
<tr><td>5</td><td>-40.2</td><td>-44.8</td></tr>
<tr><td>6</td><td colspan="2">-50.2</td></tr>
<tr><td>7</td><td>-50.2</td><td>-55.3</td></tr>
<tr><td>8</td><td colspan="2">-55.3</td></tr>
</table>

**Table 3. RSSI of different places around the public display**

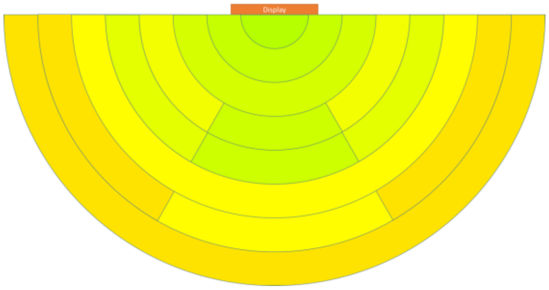


**Figure 5. Heat map of signal strength (each radius is one more meter)**

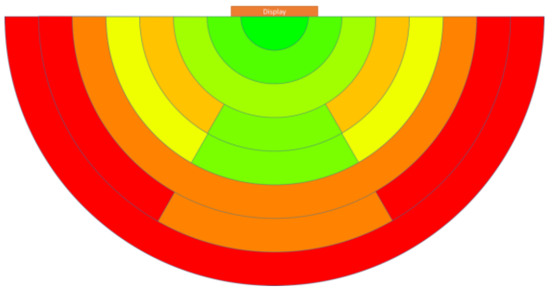


**Figure 6. Heat map with more clear colors (refer to figure 4)**

After this we decided to create boxplots which might better explain the overlaps between regions (Figure 8). We merged the regions that weren't equal according to the t-test because we believe this discrepancy is not due to a real difference but to a lack of data points.

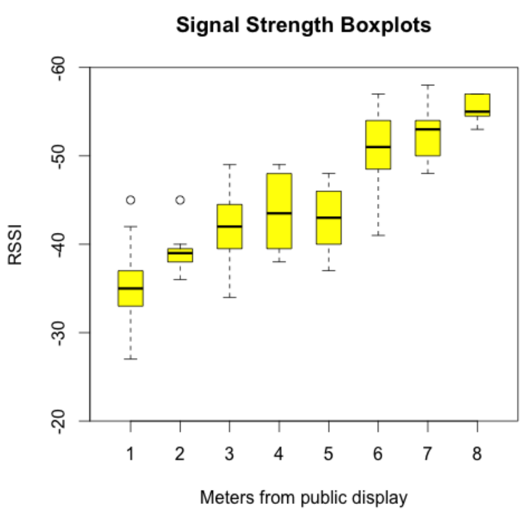


**Figure 7. Boxplots of signal strength around the public display**

As expected, some regions are hard to determine. The real problem resides in the region within 3 meters of the public display, which after observation, can contain several users, counting ones that aren't interacting with it. The detection of the closest user would have false positives specially within the close range region which is where the users would be interacting with the display.

## 4.5 User Evaluation Results

Although we have relatively small set of data to evaluate and it is definitely not enough to generalize most of people's behaviour towards human computer interaction, we have received decent feedback in the aspect of UI design. All of participants didn't spend much time learning how both the mobile and web application systems work. One issue that was observed on the mobile application was that some of the participants complained about not being able to see all the available categories that were pre-registered for the evaluation purpose at a glance. Participants are only able to search by trying many words they are interested in, and in some cases, they typed synonym words to the registered ones, and hence they weren't displayed on the device. Similarly, some of the participants mentioned that the titles on the web application, which represent each column of the content array, appear to be confusing as they are predefined words and are not instructive enough to describe somewhat arbitrary contents which are coupled together by few common aspects. They believed the categories were too broad.

On the other side we had a severe issue while using the system. Users were not able to interact with the display by a single tap. This was assumed to be a hardware issue though, if it was a wild testing the whole system would have become useless and likely made people annoyed and never to use it again.

Another big problem we had during the experiment was that the backend server was not sending the selected contents to the mobile client. We could only make approximately one in five successful data transmission to the client which is very disappointing for such kind of system, in which this is a key feature. However, we conclude that with current technology, limited time and given commodities high succeed rate would not be one of our major expectations to achieve (as seen in the system evaluation). The issue was driven by inaccurate detection of the proximity of the mobile devices.

One of the issues mentioned every time by participants was the contents updating rate, from when they subscribe to a topic till the topic is on the public display. We believe this was merely caused by the way that we performed the evaluation. Based on the result from the system performance test the system worked fine, but since in the laboratory testing the participants had to fulfil the experiment in a relatively short period of time, the system appeared to become as a search engine where people search questions and browse information conveniently just as what the participants had to do, add categories to the interest and immediately come to the display, wait until it changes, and read the content. The ideal way of fulfilling this experiment would have been deploying the system in the wild and assess how the users interact with the system and if the personalisation engages users. Instead we did it in this way because the system was not appropriately stable to be set in such an environment.

One last thing mentioned in respect to the UI design of the web application was discovered by one participant who subscribed to multiple topics at the same time, was that we can only keep two events per category at the same time on the screen, and hence he couldn't see some of the topics he had subscribed to. Since the web UI provides only two row to be displayed in the current prototype the participant had no way to search contents that he is lately interested in. This would be solved if the perspective of the system changed into more of a bulletin board instead of a search engine, as the users wouldn't be expecting to always see content that relates to all of the topics subscribed. And when more data is available, the content would rotate so always fresh content is appearing on the display.

## 5. DISCUSSION

In our study we have developed a system that personalises information to be displayed to whom is present in the vicinity. The contents are the ones generally found on bulletin boards. They are appropriate to the time and place where they are situated. When we started designing the system, a number of key points came into our consideration. First, how to measure the proximity of user interacting with display among many other passers-by. Second, privacy issues, what data to display and what data not to. Third, how to build the system so it performes seamlessly in a satisfactory manner, for example minimising the time-taken to personalise information as a user approaches and get ready by the time the user stood up in front of the display.

From the earlier phase of system designing, we went through the precedent study of leveraging Bluetooth technology from user's mobile phone to identify the device. Keeping that mind we then had debates within our team for other alternatives such as Wi-Fi signal, QR code, NFC tags and beacons. After going through a dedicated research on this, we figured out while NFC tag might bring the best accurate result in identifying users, the idea of how the users would have to deal with getting around with the system did not match with the fundamental design concept of our system. We then have come down to a decision adopting Wi-Fi signal method which would suit well for our system. Although we have had time running Wi-Fi scanning by default mode which then later turned out to be a troublesome factor that made the device invisible once it connects to a stable Wi-Fi network as the device only scans when it's not connected to one, now we forcibly operate scanning every pre-defined time so that our backend server can see it until the user physically leaves the place. System requirement in the perspective of detecting proximity of users' standing around the display remains as a problematic issue in terms of accuracy. Wi-Fi signal method has proved it obvious that the limitations toward this matter exists. With existing Wi-Fi routers we could not accurately differentiate one user over another in subtle distance. We believe that alternatives for the future studies might be to leverage beacon which would bring a better result upon this question.

Taking privacy issues into consideration may require much larger size of data set which collected from the real world users instead of what we had for this study. Based on our earlier survey conducted on a number of university students with somewhat more diverse range of user groups than which we had in the last, we have defined categories of the contents which will be shown on the display regarding privacy concerns are as follows, first data type which must not be shown, second data type which may be shown, and last data type which may be shown if there is no direct link to the source of the contents. However with given circumstance where we experienced implementational difficulties to accurately measure proximity of contacted users, we could not deploy the system in the wild settings, hence it remained quantitative data constrained for our user evaluation. We could gather three participants with identical background of computer science which in result made the user evaluation appear lacking in reliability of the result. However given that, we had one notable participant who claimed that he wants to be informed about recognition of the system upon him and highlight the contents that it personalised for him. This goes counter to what we have been acknowledged so far and thus we would like to conclude privacy concerns for this study is still open to active debate.

Working prototype wasn't just enough to deploy the system in the wild environment and let users to handle the rest without supervision. We needed it to perform in such a manner that people sees it as a smart display that is capable of personalising data in accordance with users' interest while not breaking privacy rules we have defined from design phase. In this perspective we would like to address that the system have met the requirement, it is capable of detecting users from far more distance than it would need to be and thus it has theoretically adequate time preparing to serve the right information to display. This has been proved by the system evaluation that in theory time-taken for personalising information and get it ready for the user approach to read from a distance would be more than enough as per correlating the evaluation result provided data of 28.6 seconds in average to personalise information and the walking pace of human-being which is about 5 km/h and the maximum distance a general Wi-Fi device can see mobile phones from was measured 90 meters in our laboratory setting. Altogether this would yield the result with which system capacity can fulfil serving appropriate information to the users in time. However what was observed in our study was that even the system does so, all of our participants gave feedbacks of slow transition upon the contents to display. We think this was brought up because in our user evaluation participants were asked to fulfil tasks as if it was a search engine where the user type things in and wait what contents are being displayed. We believe that this would not be an issue anymore once we deploy the system in the wild and carry out prolonged evaluation.

Overall, after all the analysis, we found the system is viable, but the design still needs some tweaking to fulfil the users' needs. Some of the users expressed that if they need information they would actively search for it and if they don't need information then they wouldn't go through the hassle of thinking what would interest them and subscribing to these topics (as our system works). In this sense it may be hard to sell the idea, but if deployed in the wild and enough data is collected, maybe the personalisation can be done behind the scenes without the user's interaction (subscribing to topics). The future works for the system would be to improve the dynamics of sending information to the mobile device from the public display, as well as redesigning the UI to better communicate what the system does, and in this way deploy it in the wild and observe how the system performs by comparing number of users approaching when the content is personalised and when it's not.

## 6. CONCLUSION AND COURSE FEEDBACK

During this project we explored a new way of utilising public displays which although are starting to be more and more pervasive, lack any useful contribution to society at the moment. They are mostly used as a new channel to show advertisements as if they were posters but most of the cases offer no real interaction. With our system we propose a way to make users more interested in this type of technologies and possibly provide a better solution to what is still used nowadays, bulletin boards, with a system that is easily maintainable in regards to the content shown. In the future could be more focused to the specific target group a specific announcement can be useful for, either based on localisation or on the type of user around it. Making public displays context aware is not something new, but we try to provide a use case for them.

We learned that what is designed is much harder to implement than thought in the beginning, and focusing the scope of project in a smaller spectrum is beneficial to test and improve the project on the long run, as changes on a smaller system are easier to make.

Regarding the course, we believe it's an interesting course, and it is quite a challenge. The workload is fine since it's basically self determined by defining the scope of the project. It would be interesting if a lecture would show what previous projects have done on other years to get some inspiration.

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