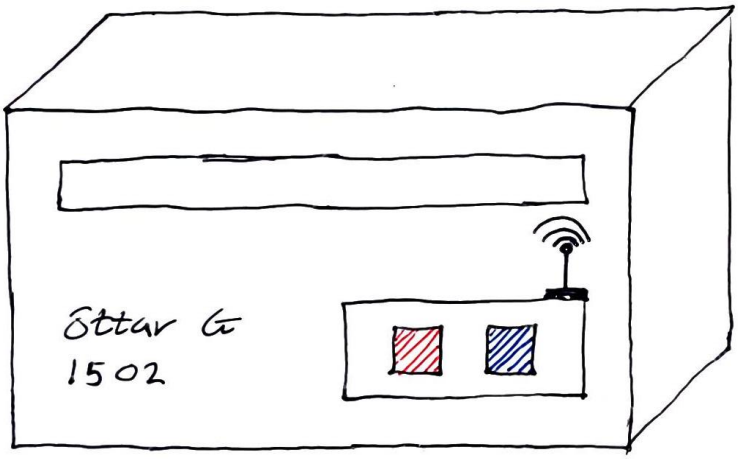
ID2012 - Ubiquitous Computing

Essay

Interactive Postboxes



Course Coordinator

Fredrik Kilander

Óttar Guðmundsson

2018 - 5 - 24

Abstract

This paper introduces the concept of Ubiquitous computing shortly and shows relative techniques that a developer could use when applying the concept in development. These techniques are then proposed to design systems to achieve natural interaction between postboxes and a mailman. Proposed systems are then evaluated using HCI Characteristics and compared to each other. Finally a discussion about the problems with their implementations is provided and the challenges that lie ahead.

Contents

Introduction on the Character of Ubiquitous Computing

When the word "computer" comes up to mind, most people think of the old PC's at their home, their laptop or maybe their favorite gaming console. This is often the definition of a computer that is commonly accepted and we do recognize them as computers when we see them. However, when a customer walks into a supermarket and the door magically opens for him he does not think of why the door opens. He simply accepts the fact that door's "know how to do it". If you get into deeper conversation about how the doors open, most often you are told that it has a sensor. Well, what is that sensor, how does it work, how does a sensor open a door? This is where the conversations get more interesting.

This kind of technology is often referred to as Ubiquitous Computing. As the author has been telling his relatives about the subject, many get confused with the topic since it sounds unfamiliar and kind of bizarre. The topic does not really explain itself, but by the English definition [0] it means that something is present everywhere. So, as we combine the word with computer, the concept molds the idea of computers being everywhere around us. But does everyone know what a computer is and what isn't? Do most people know that in their TV remote there is a small computer that sends signal to another computer inside a TV, rather than this just magically happens?

The term Ubiquitous Computing (referenced as UBIQ from now on) was coined by Mark Weisser, a researcher of the former Computer Science lab at XEROX Palo Alto Research Center. The original definition of UBIQ was described as

> *"The method of enhancing computing use by making many devices (services) available throughout the physical environment, but making them effectively invisible to the user"* [1]

UBIQ is the art of embedding assisting computers into our everyday lives that it fits naturally into our environment without us even thinking about them. As most objects in our houses are being integrated with a computer, they help us achieve certain goals without focusing on how they are achieved. As of today, computers the size of a salt grain [2] could be in more common places like clothes, food and people using Nano technology meaning all things might contain computers in a few years without us having the slightest idea.

Weiser described the best computers as quiet invisible servants [3]. In the past few years we've been delegating more responsibility to computers by allocating them with different tasks. By intuition we trust them since we know that they will do their job. Going back to the supermarket door example, the customer does not have to think that the sensor will sense him one meter away from the door and simply opens. Instead, the customer's intuition knows that the door will open so he can walk straight for the door without worrying crashing into it. Combining the computational powers of the sensor with its resources and technology it uses the application is invisible to the customer. Thus our tasks are invisibly assisted by computers.

Creating such applications is not an easy task. There are several challenges in the way to make sure that the user will not know that the computer is acting on his behalf. For instance, how will the user interact with the system? Keyboard and mouse are accepted as a part of computers, but does the user know if his eyes are being tracked or voice is being listened too? What happens as the system is moved from place to place and how does it act towards different environments? How does it scale as more devices are connected and how do they communicate reliably in terms of secure connections that does not need to be configured every time a node within the system fails?

These are just a few of many questions that need to be answered if we want to make such systems feel natural for the user. As soon as the system stops working, the user will notice, breaking the effect of the invisibility. One way to measure how well such systems relate to the field of UBIQ is determine how much they disturb the user in such a way that he notices he is using a computer. The quality of these measured are called Human Computer Interaction (HCI) characteristics [4]. In total there are 27 characteristics but there are mainly 6 that apply specifically to UBIQ. One of them, Context Awareness, describes how well the system can act on and respond to the sensed data in its environment.

In a UBIQ project that the author completed this year, a user could retrieve a shortest path through the closest supermarket to know the location of available products needed. There the system had to sense and combine multiple factors of data including the user's location, real time info from other users, location of the shop itself, the internal structure and location of the products and finally which date and time the request was being made.

The final generated context thus had to be aware of the related input that could alter the generated suggested path. The project could then be further evaluated in terms of mobility, transparent, attention, calmness and 22 other features. The idea sparked from a common problem that the author frequently encountered. By applying the techniques and methods of UBIQ to solve the problem a neat solution was constructed, receiving great feedback from friends and colleges in his program. Thus the author would like to propose a new solution using UBIQ to a common problem that he is also passionate about. How can we use similar techniques to create a Context-Aware system that blends seamlessly within the environment to help mailman delivering relevant junk mail and at the same time reduce its magnitude?

Problem formulation and motivation

Free magazine and advertisement distributors print their copies in massive bulks and deliver them into people's postboxes. Usually the postbox fills up quickly, so after 2 or 3 days it is simply thrown away or recycled.

If a person doesn't want to get these free copies, one has to glue an extra sticker to his mailbox saying "Ej reklamer", "Ej gratis ads" or something similar as seen in Figure 1. Getting junk mail having these stickers has even led to people boycotting the product, being less likely to buy it [5]. However, placement of such a sticker might save his effort of not throwing away or recycling junk mail, but that doesn't solve the problem that the advertisers are printing out waste. The mailman ends up with these unwanted copies at the end of the day and has to throw it by himself. In both cases, this produced junk mail becomes garbage and resources are being wasted. What's even worse is that half of people usually don't open them and less than 30% is recycled [6].

Figure 1 (left) *– How the author's postbox currently looks like*
Figure 2 (right) *– The junk mail that still gets through. Extra gum for scale.*

If a person would move and change addresses, he still needs to update his new postbox with the same sticker. The person that moved into his former house needs to scratch the old one off if he wanted the ads.

This is a huge financial waste, bad promoting, not dynamic and not environmental friendly [7]. The companies that pay for those ads get a false sense on how well their promotions are reaching out to potential customers since most of these junk mails are never even looked at.

In the early steps of this research, the author called an unnamed local distribution company and politely (according to his judgement) asked to not receive any more junk mail. The response was that a sticker was needed on the postbox since it was so hard for them to manage who wanted free ads and who didn't.

I don't know how the reader feels about this but surely some may feel that this is an unacceptable answer in the 21st century with current technology. Even though such systems are available [8] they are not really efficient since there isn't any system that helps the mailman know where to deliver which mail. In some cases it is possible to send a legal letter to a distribution company and ask about not receiving more junk mail [9], but this does not solve the problem for the mailman.

Modern approach

A simple approach to solve this problem could be a website or an application where people with any means of authentication could sign up to. There, a selection of what kind of ads they would like to receive could be made. Distribution companies could access that information to know exactly how many copies they need for each mailman. As the mailman would arrive to the house to deliver the junk mail, it could open an app to see who want's what kind of free copies. However, this is not a really convenient or user friendly approach.

As the mailman approaches an address he would manually have to type in that address and wait for a list of person living there. For each person he would have to read what type of junk mail should be inserted from his tablet/mobile phone and find the corresponding postbox. Scaling this up for over 50 blocks in one neighborhood with more than 40 apartments in each of them, the time for sorting and reading through the list gets tedious. Eventually, the mailman would simply get frustrated and irritated by comparing all names and addresses to a screen over 200 times per day. Most likely he won't bother going through all the names since it is quite time consuming and either dump the junk mail in all of the postboxes like happened in Figure 2 or simply skip it.

How might such a system be improved by applying concepts from Ubiquitous computing?

Natural interactions

As stated before, UBIQ is all about blending computers within our environments to make interactions feel natural and let the computers assist us without us really thinking about it. This methodology can also be described as systems being Context-Awareness which is one of the main HCI evaluation metrics.

A context-aware software is constantly sensing its environment and updating its known model based on the current context. Different dimensions of data can affect the context, such as different data sensed, users, time and date etc. As all of these dimensions are aggregated and working together to help the software understand its current situation, the software might change it behavior as it interacts with the real world. By doing so it adapts to the user and helps

him with what he is trying to accomplish. This allows software to be more flexible by creating wider range of responsiveness to human interactions.
The software context can be hinted by the five W's [10] to identify the required needs

- **Who** Mailman
- **Where** At address postbox
- **When** Any time of the day
- **What** Ads or Junk mail
- **Why** Deliver relevant content

By designing a system with this in mind, we can help the mailman achieve his goals without having him constantly looking back and forth between a computer screen and real life objects. The first clue to design such a system would be focusing on improving the interaction between the mailman and the postboxes, making the effortless. Currently, interaction is only one way. The mailman walks inside a complex, looks at postbox addresses and matches them with whatever information he has about them.

In the following section, few technical concepts are shortly described and how they can be applied to achieve two way communication between a mailman and a mailbox.

Key technologies

Radio-frequency identification (RFID)
An RFID tag is a small electronic device that can be classified as a sensor. Each tag has a small chip with computational power, memory and small antenna which is used to communicate using radio waves. When it senses a known signal ranging from 30 cm to 2 meters [11] it can respond back with information stored in the tag. They are usually really small so they can be integrated with most products that aren't bigger than itself.

Embedded systems
Computers that are created for only a few, very specific tasks can be called an embedded system. They are usually not modifiable and often come ready out of the box fulfilling expected requirements. An example such a system is a small computer inside a fridge that keeps the temperature at desired degree.

Augmented reality
AR is a computer vision technology that allows virtual objects to be layered on top of physical objects. By pointing a camera to a certain scenery, the technology can identify the real life physical structure to determine flat surfaces, known landmarks or simple QR codes. As the content is recognized, a new virtual object can be rendered on the screen with real life objects, seeming like it already is a part of that world. One of the most famous AR technologies today are the Snapchat filters using computer vision [12] or Pokemon Go [13].

Artificial Intelligence (AI)
AI can be applied to numerous sectors to help humans take decisions or simply taking them autonomously for them based on a set of trained data. The field is vast and effective in so many areas but it's worth mentioning both Computer vision and Voice Recognition. Applying them into a software, creating a softbot with weak intelligence, it could learn to identify few characteristics based on input data from either a microphone or a camera.

The Internet of Things (IoT)
As more and more objects in our everyday lives are gaining computational ability, the need for connecting them together allows further understanding of the environment. These devices are most often low powered short-range sensors that can connect to a local system or to the internet. However, the technology is still to be perfected since devices from different producers

don't share the same interoperability and are hard to configure/connect together. Furthermore, IoT systems have been under the radar of hackers and are currently very vulnerable to attacks [14]. The more systems that are connected together the more they are aware of the surrounding environment, meaning their way of actuating on the environment is enhanced.

"The sum of its parts is more than its whole." [15]

Base idea for each complex

The ground component for improving interactions will be built on embedded systems and IoT. Each block complex is equipped with a simple, hidden computer like Raspberry Pi close to the mailboxes that is connected to IoT. It would act as a server to regularly pull information from an online database about each address preferences and send a signal back to nodes within the system. Thus each mailbox will have knowledge model about its owner's interests and mail delivery services every day. As each mailbox would be equipped with some kind of sensor connected via IoT to the embedded computer, less wires would be needed and it would be easier to add or remove nodes from the system. The sensors could be powered by an internal battery or wirelessly by an antenna [16]. This makes all objects in the proposed system interactive to some degree, that is, they can react autonomously when they sense relevant data.

These sensors act differently based on the following solutions, but the idea is that by combining identification about who the mailman is, what he is carrying and the mailbox preferences at the same time, the sensed dimensions could be combined to create a relevant context. To see how these data dimensions act towards each other Figure 3 demonstrates a mock sketch up of how such joint model could be created to match each mailbox with the mailman.

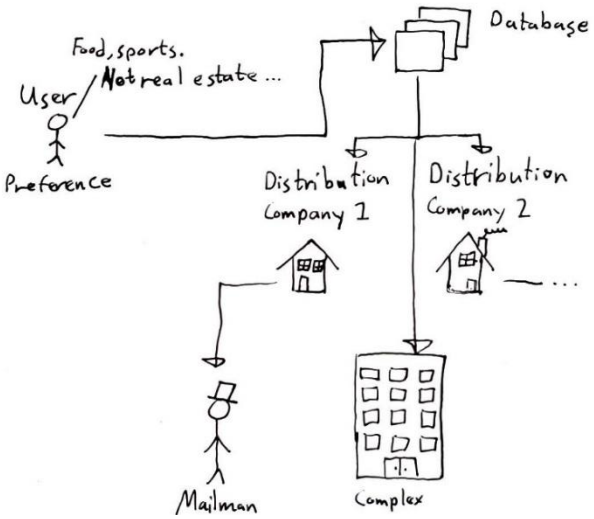


Figure 3 *– How data is passed to the mailman's sensors. The complex computer could communicate with that sensor to understand what information he provided. By doing so, a joint model of data dimension could be generated to cross reference each address junk mail interests and the junk mail the mailman carried.*

Types of junk mail

There exists nearly infinite amount of different interests and topics a junk mailed could be classified as. This is not a research material of this paper but it will be assumed from now on that there is such a that system has distinguished different types of junk mails e.g. using self-organized maps to classify by mail's attributes [17] e.g. Food, Sport, Real Estate, Newspaper and so on.

Thing to thing interaction

This section proposes two different types of systems that focus on devices communicating between each other, unknowingly to the postman approaching an address.

Sensors and LED (Figure 4)

The mailman himself is to be equipped with a sensor, being either an app in mobile phone or an RFID tag which held information about what kind of post he was carrying as he entered the apartment. Each mailbox's RFID tag would then be connected to a LED light that could display multiple colors at the same time, connected to IoT.

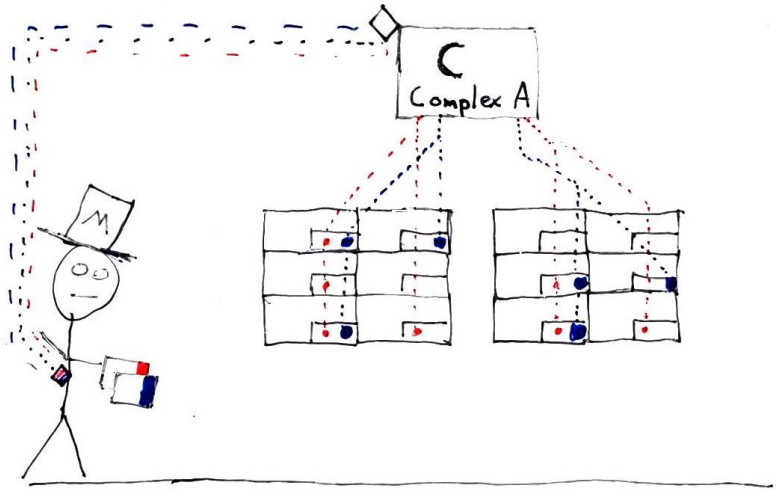


***Figure 4** – The mailman sensor communicates with the complex computer, which signals the LED sensors on the postboxes*

The LED tag would then display the colors matching the contents that the mailman has, giving him a clear simple overview of what kind of post goes where.

Augmented Reality (Figure 5)

As before, each complex has its own small computer that would take care of cross referencing preferences of addresses and junk mail carried. In this case, the mailman could use any augmented technology, either using his mobile phone camera or wearing augmented reality glasses. Each mailbox would be equipped with a sensor so as the device used by the mailman would get closer to the sensor, information would pop up on the screen.

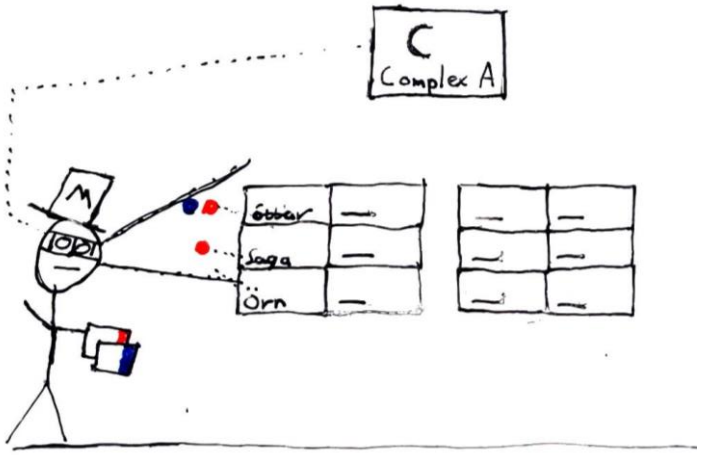


***Figure 5** – The augmented device gets information from the complex computer and as the screen approaches the postbox sensor, relevant information is displayed.*

Thing to human interaction

This section proposes two different types of systems that aims at removing the mailman's sensor out of the context. This means that as the mailman approaches the mailbox, he does not have contain a device that will somehow connect to the embedded computer in the complex. The computer can be equipped with a camera or a microphone to either use computer vision techniques to identify the mailman and the contents he is carrying or listen to what he has to offer.

Computer vision (Figure 6)

As the mailman enters the building, a camera can detect the mailman if he is dressed in some sort of uniform or simply try to identify the content he is currently carrying. Once again the embedded system will cross reference address interests and the mailman's content he is carrying and light up the LED tag inform what kind of mail should be inserted.

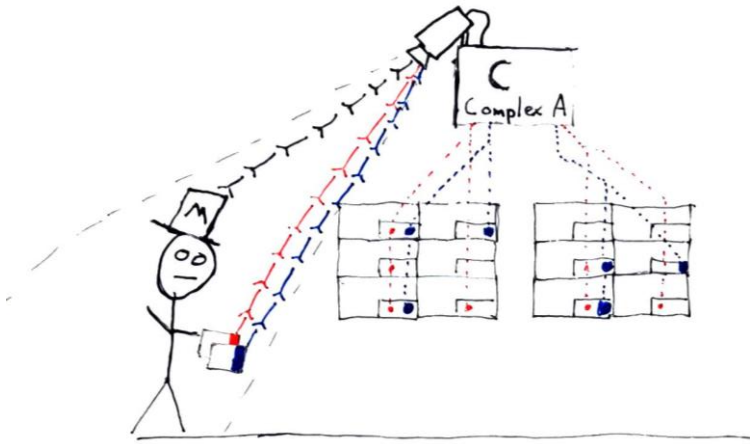


***Figure 6** – The camera on the complex computer recognizes the mailman or the content he is carrying, signaling the sensors to display matching info.*

Voice recognition (Figure 7)

To make communications feel as natural as possible, the embedded computer could ask the mailman what kind of junk mail he is carrying or what he has to offer (we could extend this to salesmen as well but that is not a topic of this report). The mailman could simply respond with his voice that he has broachers for a local restaurant, free newspaper, real estate advertisements etc. This audio could then be classified using simple Natural language processing techniques and the contents cross referenced and the LED tags would display the matched posts.

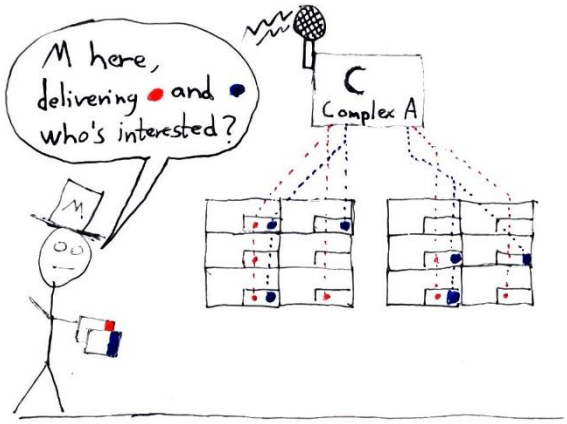


***Figure 7** – The mailman simply enters the building, states who he is and says what kind of junk mail he is delivering. The computer classifies what he is saying and sends signal to LED's that match.*

Assumptions on HCI Characteristics

As noted before, such systems can be further evaluated in terms of quality by more than 20 HCI characteristics. In [4] a list of functions is given to measure each characteristic by either a survey or data provided by testers. All of these systems are fictional and haven't been implemented, thus without proper testing it is impossible to determine the quality of their performance. However a short description is provided that hints at how successful these proposed systems might score in such evaluation.

Attention
System tries to keep the focus of the user on real-world interactions
All the systems that use the LED based method could score highly in this part. The augmented reality technique would probably score lower as augmented reality glasses are not so great in their current state. Most of them are quite expensive, limited and intrusive like the HoloLens [18] in such a way that the user will always know he is wearing a headset. Further development is needed on such glasses to make them feel lightweight and normal. The more intrusive they are, the more the glasses disengage technology from the real world [19]. Using his mobile phone would also require him to use one hand to look through the phone while inserting the post inside the postbox with the other, slowing him down.

Calmness
System only displays relevant information to the user at the center of attention. This happens only when necessary and feels natural.
Opposite to attention, the Augmented Reality system would score higher than all the LED based systems. As the mailman approaches the complex building, all LED sensors will signal the corresponding categories even though the mailman isn't inserting the junk mails. Using the AR technique, only the post box he is currently interacting with would signal the desired info at his peripheral.

Context-Awareness
Already described
All systems are based on reacting to different type of mailmen and the addresses preferences. As they all share the same context awareness they should score similarly here.

Mobility
Service continues to run as the user moves across different devices.
Even though all of them account for the mailman travelling between complex buildings, the RFID sensors and the AR glasses might run out of battery, being unable to communicate to the embedded computer. AR glasses and mailmen's sensors could also differ in quality and connectivity range. So moving between complex buildings will likely be easier if there is no risk of encountering a dead sensor unless the AI systems are really bad at their classification task, being nonresistant to noise. Thus the AI systems might score higher on this characteristic.

Transparency
The level of transparency the system can achieve to hide its computational structure from its user.
As effective as sensors can be, the mailman will always know that he needs to carry some sort of sensor to match himself with embedded computer within the complex. In the case of the battery of the sensor being dead or malfunctioning, the system will not work disrupting the mailman from the system. Using the computer vision or vocal recognition will never depend on the mailman carrying something external for identification, making him never have to worry or even thinking about not connecting to the system. In that case, the connection

between him and the system is always hidden. However, this comes down to the quality of the AI systems as well.

Benefits

The benefits of such system is various, but benefits the mailman the most. Compared to the old, basic system the experience of delivering physical post is greatly enhanced as the environment adapts to his presence and his contents. He is way quicker at figuring out what goes where without manually comparing list of digital text on an external screen.

Secondly, if all citizens would register their preferences in such a system the printing and the distribution company could tap into that information and wouldn't need to produce copies (waste) that's eventually going to be thrown away. The government knows that less waste is being thrown away, which is always a good thing for the environment and our planet. The locals who own the mailboxes could control the flow of free ads just like we can do with our emails with spam filters [20] and the companies that wants to create these ads can gain insight on the interest and demand for their product before wasting money on printing, knowing beforehand how effective their marketing is.

Discussions and criticism

As good as this system can be to ease and help with interactions, a long list of challenges lie ahead. One of the biggest problems with such a system is to make it reliable and stable. The mailman can always carry a tablet or mobile phone to access the old, time consuming system if the new one stops working or is interrupted. However, as soon as he has grown accustomed to the new system, going back will make him realize the computational infrastructure breaking the transparency characteristic. The AI designs would also need to react to mailmen's only. The system would cause quite a disturbance if a person in the hallway was carrying some kind of post that the computer might classify as junk mail or if someone yelled "pizza" and the LED's would light up.

The initial setup for such a system in a big city would be expensive and require significant amount of effort in development. Regulation of such systems and interoperability between different mailmen's would have to be standardized and security measures would be needed so hackers or maleficent persons could not syphon postbox's preferences. This is already a problem within the IT industry and very expensive to maintain. How this would be funded and maintained is not a topic of this paper but could be done by the government to help its goal to reduce carbon footprint.

Furthermore, developing such systems and installing them in every complex might also be an overkill depending on the future based on environmental factors. In past years, more people are aware of the damage that plastic, paper and other waste is doing to our planet. With the power of the internet advertisements and information technology it is way easier and more efficient to reach people with matching interests of the product. So maybe in the near future, governments might ban the production of junk mail entirely, rendering the whole system useless.

Figure 8 *– Triangle of objectives*

If this improved system would be put into the Triangle of objectives [21] we see that all scopes would like to be met. This is however impossible to achieve, but the suggested scopes would be Cost and Quality. The reason for that is because the only way for the system to be easily integrated into the community is if it is affordable for everyone. If quality wouldn't be maximized the system wouldn't even be used at all or at least wouldn't be able to adapt to future changes or different environments. The earlier the system would be put to use the better, but rushing this would subtract the values of the other two aspects.

Finally, would humans find it worth it to have such a system in place? This will greatly help the mailman but the people living at the complex might even not bother since they don't really care for the mailman. For some people who can't see the bigger picture of the waste produced and the needs for recycling won't mind stockpiling their post every week and throw it in the common garbage on their way out.

"It can be difficult to predict, especially about the future" [22]

Conclusions

As several advanced techniques are combined when designing system with UBIQ in mind, a more human friendly approach can be taken towards interacting with the system. Making these interaction feel natural and simple, enjoyment of working with the system could be increased and it could in some cases speed up the process. We have shown how these possible techniques might be integrated within the environment and hinted pros and cons of each implementation.

Designing such a system is no easy task though. Planning and standardization of multiple sensors and software types is something that has to be carefully thought of. For the interactive postbox perspective, such a system would require easy installment in different environments and also be able to support different services which is already hard with most modern systems. The context that the system needs to understand might vary a lot depending on different locations and the humans interacting with it. To make such a system scalable and really implementable, more research is required with further field testing so it can be properly evaluated.

_____

Óttar Guðmundsson

References

[0] Ubiquitous [Def. 1.] Cambridge Dictionary. In English dictionary. Retrieved from: https://dictionary.cambridge.org/dictionary/english/ubiquitous

[1] Mark Weiser, "The computer for the 21st century", Scientific American, September 1991, pp.94-104. Retrieved at https://www.lri.fr/~mbl/Stanford/CS477/papers/Weiser-SciAm.pdf

[2] Sommerland, Joe (2018, March 20). *"IBM Unveils world's smallest computer"*. Retrieved from https://www.independent.co.uk/life-style/gadgets-and-tech/news/ibm-worlds-smallest-computer-blockchain-think-2018-conference-a8264841.html

[3] Weiser, Mark (November 1, 1996). "Computer Science Challenges for the Next 10 Years". Retrieved from lecture: https://www.youtube.com/watch?v=7jwLWosmmjE

[4] Quality characteristics and measures for human–computer interaction evaluation in ubiquitous systems 07 July 2016 Carla Ilane Moreira Bezerra, Rainara Maia Carvalho Retrieved at https://link.springer.com/article/10.1007/s11219-016-9320-z

[5] Leonard, Forum comment, 14.Sep.2007, 08:55 AM, The Local. Retrieved at https://www.thelocal.se/discuss/lofiversion/index.php/t10904.html

[6] NYE Law (2018). "Junk mail" Retrieved from: http://www.law.nyu.edu/about/sustainability/whatyoucando/junkmail

[7] Velasco, Alan (2009, May 19) "*Carbon Footprint of US junk mail equivalent of 480.000 cars"*. Retrieved at https://matadornetwork.com/change/carbon-footprint-of-us-junk-mail-equivalent-to-480000-cars/

[8] SWEDNA (No date registered) "Nix Addresserat". Retrieved at http://www.swedma.se/reklamsparr/nix-adresserat/

[9] Information Commissioner's Office (No date registered) "Junk mail". Retrieved at https://ico.org.uk/for-the-public/junk-mail/

[10] Kim, Don (2016, July 28) "Project Management 101: The 5 Ws (and 1H) that should be asked of every project". Retrieved from: https://resources.workfront.com/project-management-blog/project-management-101-the-5-ws-and-1-h-that-should-be-asked-of-every-project

[11] Sky RFID Inc. (No date registered) "RFID Tag Maximum Read Distance". Retrieved from: http://skyrfid.com/RFID_Tag_Read_Ranges.php

[12] Arcangel, Aubrey (2018, Jan 29) "Snapchat filters: How do they work?" Retrieved from: https://arvrjourney.com/snapchat-filters-how-do-they-work-1d3451c8d048

[13] Warner, Claire (2016, July 13) "How does "Pokemon Go" work? Here's everything we know about the tech behind the augmented reality fad". Retrieved from: https://www.bustle.com/articles/172317-how-does-pokemon-go-work-heres-everything-we-know-about-the-tech-behind-the-augmented-reality

[14] Roe, David (2018, Feb 7) "7 Big Problems with the Internet of Things". Retrieved from: https://www.cmswire.com/cms/internet-of-things/7-big-problems-with-the-internet-of-things-024571.php

[15] Philosiblog (2016 Mar 17) "The whole is more than the sum of its parts". Retrieved from: https://philosiblog.com/2016/03/17/the-whole-is-more-than-the-sum-of-its-parts/

[16] Smiley, Suzanne (2016, Feb 5) "RF Physics: How does energy flow in an RFID system?" Retrieved from: https://blog.atlasrfidstore.com/rf-physics

[17] Hollmen, Jaakko (1996, Mar 8) "Self-Organizing Maps (SOM)". Retrieved from: http://users.ics.aalto.fi/jhollmen/dippa/node9.html

[18] Kleinman, Jacob (2018, Feb 14) "Augmented Reality Glasses: What you can buy now (or soon)". Retrieved from: https://www.tomsguide.com/us/best-ar-glasses,review-2804.html

[19] Ambinder, Mike (2009) "VALVE's approach to playtesting: The application of empiricism". Retrieved from: https://steamcdn-a.akamaihd.net/apps/valve/2009/GDC2009_ValvesApproachToPlaytesting.pdf

[20] Nield, David (2018, Mar 14) "Five tips for blocking spam from your inbox". Retrieved from: https://www.popsci.com/stop-spam-emails#page-4

[21] O'Toole, Garson (2011 Jun 20) "Quote: It is difficult to predict, especially the future (variant in English 1956) (attrib Neils Bohr 1971); Question about Danish text". Retrieved from: http://listserv.linguistlist.org/pipermail/ads-l/2011-June/110337.html

[22] Dennis Lock, 2007. Project Management, 9th ed.p21-24 https://saadsohail.files.wordpress.com/2011/05/pm-book.pdf

All references were last accessed 2018.5.23 19:47