“The ability to transform any space temporarily into a smart space is a powerful capability”. What are successful implementations of smart spaces? Should the implementation of physical smart spaces be entirely replaced by transient smart spaces?

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1. INTRODUCTION

Smart devices have been established as viable everyday gimmicks, and their number increased exponentially over the last decade. A smart device is a device able to communicate with its surrounding devices via a connecting technology, i.e. Bluetooth, Wi-Fi, NFC and so on. To simplify this definition of a smart device, it is a device that can think; a device with an embedded processor, of any speed and frequency which is wireless capable, with examples such as a smartwatch, a smartphone or a smart TV. However, these are just a subset of the now common entity, the Internet of Things. Following the smart devices, comes the smart space, the main focus. A smart space is a space where smart devices and integrated sensors are surrounding the perimeter, communicating with each other over a dedicated network, processing data, analysing the environment/users and eventually allowing users to live an easier life by gathering everything a user can control in a single interface as Cook et al. suggest, (Cook and Das, 2005). Nonetheless, this does not necessarily mean that data cannot be fetched or sent from or to a device outside the boundaries of this space. In fact, in the context of smart spaces, the word space is only meant to describe a confound environment, but does not limit the reachability and extend of communication with devices in remote locations.
The main factors that will be discussed below, are a result of the paraphrase by Mahadev Satyanarayan, the founding Editor in Chief of IEEE Pervasive Computing, during an interview (Ebling and Want, 2017). He suggests that being able to transmute any space into a smart space transiently is a prevailing functionality. Focusing on the conceptual meaning of these quarrels, comes our next and final definition. A transient smart space is, as the name suggests, a temporary solution to having physical smart space capabilities on the go; a subset of physical smart spaces. That is, with the use of mobile devices and artefacts that are themselves smart, but are not limited by input from stationary sensors.

2. EXISTING AND SUCCESSFUL IMPLEMENTATIONS

Physical smart spaces are still a work in progress, and currently not everyone can afford one. The technologies involved are simple as independent entities, but complex as a whole. On the other hand, a transient smart space can be given birth by a single smart device, which is simpler, but will suffer from the limited capabilities it can offer when compared to a physical smart space.

2.1 Physical Smart Spaces

Physical smart spaces must be deployed correctly, all the sensors, and the server and other input devices must be set accordingly with the consumer as the person of interest, and the degree of complexity can range from low to extremely high, (Ricquebourg et al., 2006). In their paper, Ricquebourg et al. discuss the various technologies required to produce a smart environment, and the immediate implications that may arise.
Given the difficulties of constructing a smart space, companies offering their expertise are available, who are able to transform the consumer's desired environment to be permanently smart. Loxone is one such company, by advertising their expertise on renovating any space to include cutting edge technology, and focuses mainly on energy consumption and sustainability, (Loxone Smart Home Automation UK, 2017). Specifically, some of this company's work, found in their case studies, consists of revamping homes, offices and, in one case, a church, where they took responsibility of placing all the required components, sensors or RFID tags, making them transparent to occupants and finally installing the white appliances in addition to smart bulbs, smart blinds, generally smart everything. Loxone provides the occupants with an app interface, Loxone Smart Home App, in which they can control all these devices as well as keep an eye for maintenance, while they are not present in the smart space, all because of the brains of the operation, a "mini" server which connects all of the various components and processes data adapting the environment to the user's liking. These smart homes are also voice controlled and this entails that Loxone is in par with the statements made by Ricquebourg et al., as well as the similar paper of Balandin et al., which lists the key development aspects of smart spaces, (Balandin

and Waris, 2009). Figures 1 and 2, show an example of a smart home and how all of the appliances, sensors and other components are interconnected through the “mini” server.

Figure 1 - Taken from Loxone website. Show the expansion of the various devices interconnected in a dedicated network.

Figure 2 - Taken from the Loxone website. Shows the network architecture together with the brain of the operation: the "mini" server.

Due to the above-mentioned complexities, a company such as Loxone will not rush into creating this smart environment. Instead they will spend hours designing and evaluating ideas before implementing anything. To save time in designing they could use one of many different Ubicomp Space designer’s tools that are about to make way into smart spaces rapidly. A designer’s tool worth mentioning is miniStudio, with its large range of capabilities in designing such spaces in a fraction of the time required to do so without this tool, (Kim, Kim and Nam, 2016). A disadvantage of physical smart spaces is the time required to design and complete a smart environment, and with miniStudio designing and evaluating miniature representations makes this disadvantage obsolete and unimportant.

2.2 Transient Smart Spaces

Transient smart spaces are not as straightforward as physical smart spaces since they are just abstract. This is due to the fact that a physical smart space by nature has multiple permanently stationary components, sensors, that have a dedicated task, provide data as input, whereas a transient smart space, is a space where wirelessly connected smart devices have to coincide to perform a task, or work independently to perform a more specific task. Therefore, the following paragraphs will emphasize mostly on the devices that could be used to set up a transient smart space.

A potential smart device is the Lenovo Yoga Tab 3 Pro, which can be used either as a tablet, a personal computer or even a projector, which is itself integrated and can be rotated to the user's liking. With this power, the Yoga Tab 3 pro, can project any image or video on a wall up to 70 inches large in diagonal. That is extremely impressive when you realise that all of this is packed in a 10-inch tablet only a few mm in thickness. A powerful projector is retailed at about twice the price of this tablet, which is perfect for travelling and it is probably a fraction of the projector's weight and size. As Lenovo advertises, it is a "Tablet that can actually replace a TV" and this can clearly be observed in Figure 3.

Figure 3 - Taken from Lenovo website. The ability of the Lenovo Yoga Tab 3 Pro to project on any surface.

While searching for devices that can potentially transform a non- smart space into a functioning smart space, one can stumble upon the term Mixed Reality (MR). This term coincides both the aspects of Virtual Reality (VR) as well as Augmented Reality (AR). Roo et al., discuss the power of mixing virtual, augmented and actual reality to enhance learning and expertise in areas that are hard to abstract, with examples such as an immersive volcano eruption for educational purposes, using all 3 of these realities, where students are able to interact with the models, calling it "One Reality", as can be seen in Figure 4, (Roo and Hachet, 2017). This creates numerous questions, on what is real and what not, as if the time space is separated into 3 dimensions and a user can interact with any of these dimensions, with hand gestures, as seen in Figure 5. Therefore, a place can immediately be transformed into a smart space temporarily with the use of HMDs. Such HMDs exist but have not yet reached these potential functionalities. One example is Microsoft's HoloLens and Cowling et al. discuss on how the HoloLens could be used properly to get the most out of this amazing device, (Cowling et al., 2017). Although HoloLens focuses mainly on the AR dimension, nothing stops it from closing the "blinds" and producing full virtual environments with its amazing graphical fidelity to immediately change dimension and enter the world of VR.

Going back to Mahadev's statement, a HoloLens can easily transform any place to a smart space and that is done transiently with the use of a single device and, of course, the World Wide Web. The user can augment multiple screens onto any surface of a physical space, get information on weather, sports or series and interact with nearby devices to control the functionalities or to just find these devices in case the user cannot locate their whereabouts. Another example of such a device is Google Glass. Google Glass is the social alternative to HoloLens due to its slick design which resembles plain sunglasses. Of course, a user does not have all these functionalities that the HoloLens offer due to its low graphical fidelity, which Google intended to enhance mobility and appearance, but nonetheless provides a simple and fast smart space on the go. Both these devices allow users to directly interact with AR or VR objects while also keeping the useful aspects of physical reality in place, although the Google Glass may not be able to completely immerse a user into VR.

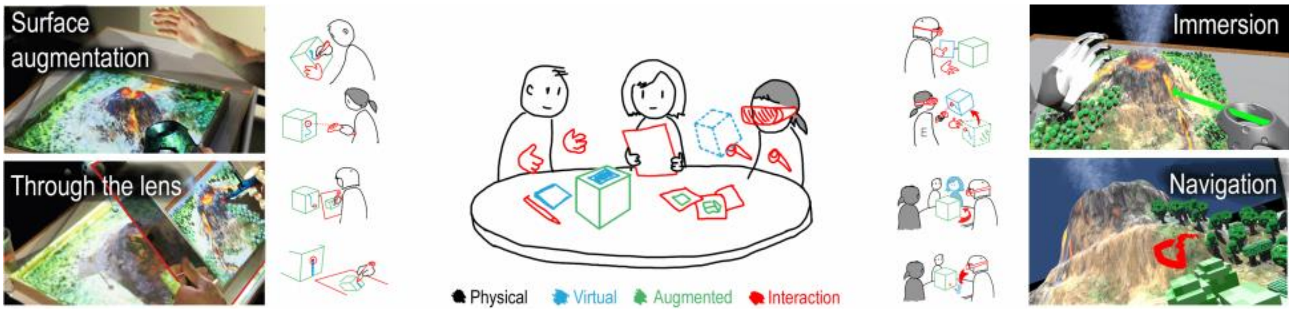

Figure 4 - Taken from One Reality research paper by Roo et al. Shows how an educational smart space can be combined with a technology such as HoloLens

Figure 5 - Taken from Google Images. This image shows the capabilities of Microsoft's HoloLens and how anything can be augmented into the physical reality

When asked about transient smart spaces, Mahadev suggested a few devices that could potentially aid with this ability to transform any space to a smart space. Specifically, he talked about a prosperous project which studies the existence of projected keyboard on physical surfaces by mobile devices, (Wang et al., 2014). Wang et al. called this concept virtual keyboard UbiK, and keystrokes are recognised by "fine-grained, centimetre-scale sound source localization, using the multipath channel profile as location signatures". Although this keyboard is designed to perform the single task of providing a projected keyboard, the space is actually transformed into a smart space temporarily where the mobile device records the surrounding environment and decides how to project the keyboard layout.

3. DISCUSSION: PHYSICAL VS TRANSIENT SMART SPACES

Mahadev Satyanarayan's disputes, sparked a conflict between these two alternatives. On one hand we have the comfortability, long lasting (permanent) ability and stability that a physical smart space can offer. On the other hand, we have the portability, rapidness and scalability of a transient smart space. So how does one decide which is more powerful, based on the task at hand? The answer could be simple but instead more questions arose. Can transient smart spaces completely replace physical smart spaces? Can temporary, on-the-go solutions keep up with permanent and rigid solutions in terms of processing power and efficiency in energy consumption? In order to reach to a conclusion and provide answers to the above questions, the only logical path one may take is to introduce scenarios where these two alternatives can battle head to head.

3.1 Scenario 1: Smart Offices

Naturally, to improve on the performance of employees, a company would want to create an environment where the physical objects can interact and perform tasks automatically for the employees, an environment where the space around the employees can adapt and eventually increase their satisfaction.
The scenario at hand is stated below:

"Suppose an employer decides to call a conference meeting to discuss issues related with that day's topics. The employer wants to inform all employees necessary for the task and get the conference room ready for the meeting. Additionally, the employer decides that since it's the birthday of one of the employees, to throw a surprise party right after the end of the meeting."

In the case of a physical smart space, a company like Loxone, could use a designer's tool, i.e. miniStudio, to picture a potential design for the office space. Then using their expertise, set up the various sensors, controllers and servers for the internal office network devices to be able to account input data such as how many people are in the conference room, cafeteria etc. Using this information, the server would configure smart devices and appliances to maintain the temperature at a nice 19-21 degrees Celsius, depending on the occupants at place, provide light by opening blinds if there is still daylight and so on and so forth. When considering the conference room meeting, the employer would be able to, just by using a smartphone or voice commands, "inform" the selected employees for the meeting by either sending room location and a schedule to their email addresses or directly display a message on the monitors embedded on the walls in their offices. Once the selected employees are gathered at the conference room, the server sends the commands to shut off blinds, dim the lights and turn the projector on, based on the input from proximity sensors that everyone is gathered. When the meeting is over, the employer would demand "Switch off projector". At that time, the server immediately switches off the projector, opens the blinds and checks the employer's calendar to figure out what is next. The server then sees that it is an employee's birthday and turns the speaker on playing the happy birthday song. Once the surprise party is over, the sensors' input suggests that all employees left the room, so the server sends the commands to shut everything off in that room. For such a scenario one might want to consider the words of Ryu et al., where they analyse how a smart office could be setup to work extensively with the Internet of Things to provide simple approaches to complex tasks for employees, (Ryu, Kim and Yun, 2015).

For the transient smart space case, this would not be entirely possible. Based on the permanent aspect of the office space, the logical solution would be to allow the various comfortabilities throughout the life span of the company. Given some of the devices mentioned above, though, one could be able to set conferences on the go, an ability that a physical smart space lacks. For example, a salesman travels to pitch a new product. Having a Lenovo Yoga Tab 3 Pro would be ideal, if the alternative was to carry a full-sized projector. The settings on the Lenovo Yoga Tab 3 Pro would be personalised on the sole user, that being the salesman, but that would not be visible when using the integrated projector and therefore invisible to the potential clients.

3.2 Scenario 2: Vacation and Work

During their career, a lot of people experience anxiety and stress related issues, that seem to go away with a holiday, either that being abroad or nearby. This leads to our next scenario.
The second scenario:

"An architect wishes to take a few days off to travel to a tropical destination. Nonetheless, due to unfinished projects and upcoming deadlines, the architect must be able to work a day or two when arriving at his/her destination. There are various software and techniques that are required when producing architectural designs."

The first thought on anyone's mind is for the architect to carry a laptop and finish the job, but the architect got intensely attached to using multiple displays and a graphics tablet coupled with a stylus to draw the plans of a building. When thinking about this, the architect created a smart space at the office that perfectly suits his/her desires. To accomplish this on the trip, the architect can only carry a HoloLens, the device that can reproduce exactly the architect's usual workplace. With the ability to have multiple augmented displays on physical objects or floating in front of the architect's visual field, and the ability to use gestures to draw 3D models the architects feels just as home and finishes the job at hand without any difficulty.

Alternatively, in this scenario, the physical smart space is not at all applicable, even if the hotel the architecture was staying provided smart facilities, this would not constitute directly to the architect's liking. A physical smart space would be possible if the hotel was built with architects in mind, which is never the case.

Each scenario was one-sided purposely, to show that different situations call for different measures, in this case, different smart spaces.

4. CONCLUSION

The topic surrounding smart spaces turned out to be quite controversial, based on where and when each type of smart space can be optimised. Mahadev is correct in saying that the ability to transform any place temporarily to a smart one is a powerful capability. Nonetheless, with the current development of technology, a transient smart space cannot reach the full potential of a physical smart space, or vice versa. With physical smart spaces, input from stationary devices can in turn maintain a comfortable environment for occupants of that space, personalised on the desires of a number of people. With transient smart spaces, though, the personalisation level falls on the desires of a single user at once. Therefore, other than the trade-off of using battery powered devices that may in turn switch off, the other trade-offs between physical and transient smart spaces are personalisation levels, public vs private constraints and of course processing power, since devices used in transient smart spaces are integrated and unchangeable. Nonetheless, a world which both physical and transient smart spaces can coexist would be the optimal solution as there are certain situations where one might outperform the other and vice versa, a smart world, (Liu et al., 2017).

> *"Smart world is an attractive prospect involving penetrative intelligence into ubiquitous things, including physical objects, cyber entities, social people, and human thinking."*
>
> *Liu et al. 2017*

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