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Industry 4.0: Is It Time for Interaction Design Craftsmanship?

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Abstract: The technological innovation of Industry4.0 opens up new possibilities for bespoke and unique designs all rooted in the same technology and supported by the same services. Taken together, Cyber-Physical Systems, Cloud Computing and Internet of Things offer a neutral platform for the creation of hybrid digital physical objects. The economy of scale is reached by sharing the same technology across different projects and potentially very different domains. This vision is illustrated by the work done in the meSch project and its platform for the production of novel interactive experiences in museums. Six installations designed by recombining the same electronic components and the same services are used as a case study. They show how the meSch platform is aligned with Industry4.0 principles of enabling dynamic composition, supporting distributed production, and monitoring use for service improvement. As a platform it supports single-piece production and empowers designers to create bespoke solutions with the same technological core.

Keywords: Interaction Design, Internet of Things, Cloud Computing, Museums, Personalisation

1. Introduction

Funded in Germany to take advantage of cutting edge digital technology for manufacturing, "Industrie4.0" (aka Smart Factories/Manufacturing) has sparked worldwide discussion on what it will bring (Löffler and Tschiesner, 2013)(Wahlster, 2013)(Lasi, et al, 2014)(Zhou, et al, 2015). The combination of Cyber-Physical Systems, Cloud Computing and Internet of Things is expected to be a game changer in the production, distribution, use and disposal of goods. Although a precise definition is still to be agreed upon, principles are emerging: products and machineries have embedded knowledge and can rearrange themselves without (or with minimal) human intervention; widespread standards enable highly modular production to be distributed, possibly across different factories/service-providers; interconnection of goods and services allow to collect data and to track products lifecycle and their use (Hermann, et al, 2016). The impact is expected to be huge on industrial production as it fosters standardisation: the possibility for the same machineries and services to be automatically reconfigured to be used for the production of different goods is seen as a means to implement mass customisation on demand, i.e. the production of small batches, with the

same reliability and quality of mass production. In a scenario (from Wahlster, 2014), a single customer uses an online "smart shop" to create and order their own favourite combination of breakfast cereals, fruits and nuts. The order is then automatically implemented by the conveyor belt that adds only the chosen ingredients before the final product is packed and shipped to the customer. By monitoring the whole customer-base and their purchasing habits, it is possible for the company to collect large data sets that are then analysed to optimise the supply chain of ingredients or the packaging (i.e. creating multiple package sizes to match different sizes of orders). The impact on the design of products and services is clear: as the product itself transforms the process, the split between design and production is called into question as it fragments and decentralises it to enable dynamic reconfiguration (Löffler and Tschiesner, 2013). This industrial revolution opens up new possibilities for bespoke design that can exploit the "production of batches of one" to focus on the values and experiences of the individual as opposed to optimising the production process. In other words this technology-driven innovation enables a strong application pull (Lasi, et al, 2014).

Seen in this perspective, Industry4.0 holds much potential for interaction design to explore single-piece designs, all rooted in the same technology and supported by the same services. Taken together, Cyber-Physical Systems, Cloud Computing and Internet of Things offer to design a powerful but neutral platform. Microprocessors, communication, sensors and actuators (the building blocks of Cyber-Physical Systems), can be composed to create reactive spaces and smart objects that seamlessly integrate with their surroundings: the interaction is no more with what is obviously a digital device, but with objects that look everyday whilst augmented with concealed digital technology. The Internet of Things then connects these smart objects with their online shadows allowing tracking of what happens to each of them in the real world, for example by continuously sensing the environment or interacting with people. This data collected through Cloud Computing is aggregated and used in whatever way, i.e. to change the behaviour of the object themselves or to offer new services. Taken together, the three key components of Industry4.0 form an infrastructure able to support a new form of craftsmanship centred on interaction design: each design is unique, but shares the same infrastructure with the others while offering the user / consumer a very different experience. The economy of scale is then reached through sharing the same technology across different projects and potentially very different domains.

Using as case study the research and outcome of meSch, a European project for the easy production and deployment of tangible interactives for heritage and museums, I will first discuss the infrastructure used to co-design and co-create a number of bespoke installations from the same hardware kit. Each bespoke co-design engaged curators, product designers and computer scientists while the co-creation and implementation was distributed. The visitor's interaction was logged to extend the experience beyond the visit and to collect Big Data on use. I will then discuss the potential of the meSch platform beyond its current application and conclude reflecting on the transformational impact such a shared infrastructure across domains could have on interaction design.

2. Designing Tangible Interactions in Museums

The ever-expanding range of elementary computational elements and the pliability of digital content allows us to radically rethink interactives in museums away from mobile technology (phones or tablets) toward bespoke design that brings *that* specific place, object or story to life in immersive experiences where technology complements heritage (Petrelli et al. 2013) (as opposed to competing with it for the visitors' attention as shown in (vom Lehn and Heath, 2003)(Hornecker, 2008)(Szymanski, et al, 2007)). Pervasive computing (the technology that underpins the Internet of Things) then becomes an additional material in the exhibition designers' toolbox: it offers new ways of engaging visitors with digital content through tangible interaction. This section briefly reports a few interactives created by the meSch team to illustrate how the same computational elements have been reused to create different experiences.

2.1 The meSch Platform

The meSch platform is composed of three layers (Figure 1): a set of online services offered to museums and heritage professionals; a cloud computing connector that synchronises the editing done at the service level with the Internet of Things (IoT in the following) that composes the physical installation used by visitors (the lower layer). The service layer supports a set of different activities: *meSch.io* enables museums and heritage professionals to create their own interaction templates and deploy them onto their specific IoT. A template maps pre-prepared content (i.e. multimedia files) with the specific context in which it will be delivered, i.e. when a specific combination of factors occurs such as the visitor is at a specific point of interest and uses a certain object then a given video is played (as described in the next section).
meSch share supports a community of professionals to exchange (or sell) templates to be reused, repurposed and modified to work in a specific museum.
meSch Viz uses the same set of log data collected in the exhibition to offer two different services: to the museums it offers an interactive visualisation of the overall logs (i.e. all visitors) and enables the analysis of visitors' behaviour with respect to the museum's own expectations, to the visitors it offers a personalised website based on the individual pattern of visit combined with extra content provided by the museum and, possibly, other online content repositories.
The middle layer is the Cloud Computing component that includes: the storage of the templates for each user, the communication component for the deployment of the templates onto their respective IoT instantiation and the collection and storage of the logs from the exhibitions.
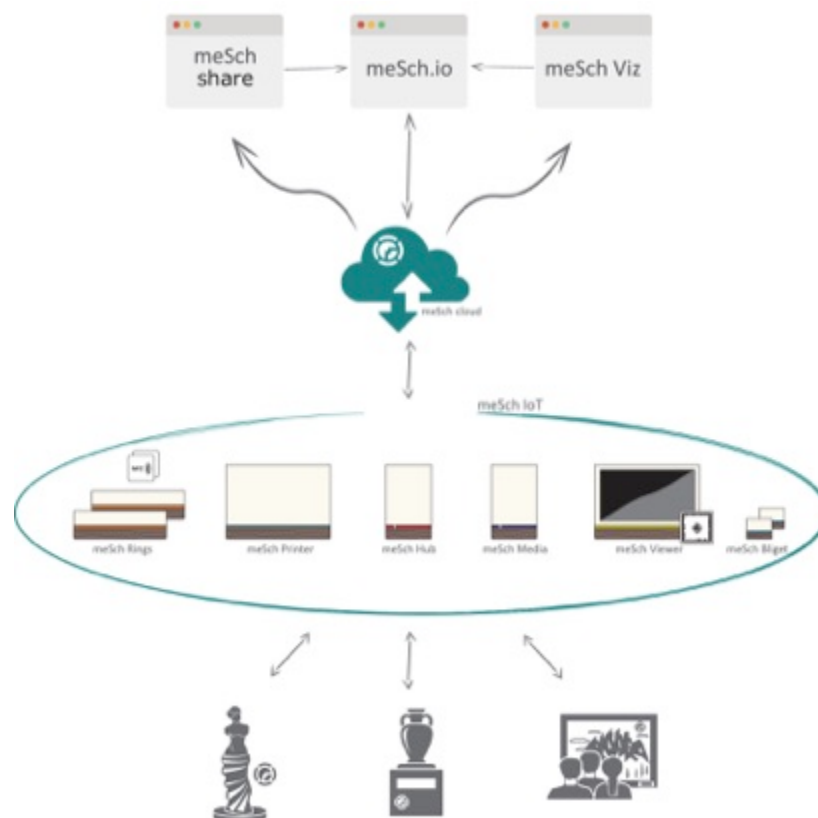

Figure 1. The overall architecture of the meSch platform: (from top to bottom, by layer) the online services offered to the museum professionals include a selection of templates to reuse (meSch share), an editor to compose / change the templates (meSch.io), a visualisation service for the collected visiting logs (meSch Viz). The online services are in the cloud that also communicates with the Internet of Things layer located in the museum.

The lower layer is the specific installation in the museum / heritage site. It is represented in Figure 1 by a range of different devices created by meSch to implement the IoT; the devices are all network-enabled and orchestrated by the Hub, a Raspberry PI unit that also manages the communication with the Cloud. The devices are combined in different ways depending on the installation. Each device has a corresponding information shadow in the Cloud. Devices that are currently implemented include NFC technology (Rings), thermal Printer, multiple Sensors, an Augmented Reality set (Viewer), and nodes for the delivery of multimedia content (Media). The role of the IoT layer is to execute the interaction with the visitors as well as to collect visitors' data to be passed, via the Cloud, to the Viz Service.

The meSch platform was designed around its potential users and offers a simple but powerful user interface that enables professionals to: define their own specific IoT setting (i.e. which combination of devices will be deployed on the exhibition floor), define a set of conditions (the context in which a specific content will be delivered), upload multimedia content using the meSch.io service; tune the interaction behaviour, and deploy the whole package to the IoT setting for immediate testing. This close and quick cycle from conception to test fosters design thinking in museums that can experiment with possible implementations before decisions are taken; this process is very rarely done (Smithsonian, 2002). This was demonstrated in a number of events organised by the meSch project where curators created bespoke interactive installations over a weekend starting from historical objects selected by the hosting organization.

2.2 From NFC Technology to Interactive Installations

To illustrate how the meSch infrastructure supports bespoke designs out of the same technology, I use six different interactive visitors' experiences created by recombining the same set of digital devices. The purpose is to show the added value that 'designing for the specific' offers to achieve a higher visitor engagement. While the six interactives have been all implemented and tested, three of them were put on display in public exhibitions in three different museums and were used by over 20.000 visitors; the other three were for experimental explorations.

The core technology for all the six installations is Near Field Communication (NFC) by which a device can exchange a limited amount of information with an active tag when placed at a very short distance (less than 4-5 cm.). Most of the time the data goes from the tag to the device (read-only NFC), although some models can store a minimum set of information in the tag itself (read-write NFC; the models we used stored 1K). NFC is the technology behind contactless payment with credit/debit cards and it is therefore well tested and robust thus suitable for large-scale use in museum exhibitions. All installations used the same combination of devices: one or more Ring to read/write NFC and one or more NFC tags; each Ring communicates with the Hub that controls the deployed IoT; the Hub also controls one or more Media node that will deliver the content file when a specific condition is true. Three installations also used the Printer to create a personalised souvenir based on the interaction log recorded by the NFC tag or the Ring depending on the setting.

Narratives in the Trenches of WWI was an exploratory prototype designed to test the concept a place telling the many stories of the people who lived there (Petrelli et al. 2016, Marshall et al. 2016). It is composed of a set of Bluetooth-enabled loudspeakers encased in wooden lanterns positioned at points of interest in the trenches and fortified camp of WWI on the Italian Alps; the lanterns are paired with an interactive belt that hosts the NFC reader and a set of 4 cards (NFC tagged), each one representing a different theme. The interaction is triggered by presence: when the visitor wearing the belt enters the range of a loudspeaker, a loud sound is played and attracts the visitor; when the visitor is about 5m away the loudspeaker plays the story on the theme (the card) currently in the belt. The visitor can then change the card and listen to a different story or move away and continue the visit. (Figure 2)

Figure 2. The interactive belt designed to be used while trekking in the Italian Alps visiting the trenches of WWI. (top row) The belt and the thematic cards are worn by the visitor while the Bluetooth-augmented loudspeaker marks the point of interest. Visitors in group negotiate what to listen to next. (bottom row) Each of the seven places is marked by a lantern that conceals a Media node that plays the sound / stories; the four cards are NFC tagged; the belt hosts both the Ring to read the tags and the Hub to communicate with the Media nodes.

This was a single interactive installation in a larger exhibition on *Greek Movement*. It aimed to recreate the movement of the paintings in the cup when liquid is poured in it. A set of kylikes (cups with a shallow bowl and a tall stem) were displayed in a case; in front of the case was a 3D printed replica of a kylix next to a set of round slots to fit the base of the kylix. Hidden in the kylix base was an NFC tag while the slot had a Ring each: when the kylix replica was placed on a slot the animation inspired by the kylix for that slot was projected by the Media node positioned above the interactive station. A panel invited visitors to try the interactive experience of placing the kylix in the slots, look at the animation and imagine the amazement of the ancient Greek when the fish in the bowl would look like they were swimming. (Figure 3)

Figure 3. The kylikes installation at the Greek Movement exhibition. (top row) In front of the display case a 3D printed replica invites viewers to place the replica in the slot; this will project an animation of the moving decoration inside the kylix replica. (bottom row) The installation uses a single NFC tag placed at the base of the kylix replica, three Rings below the slots and three Media nodes placed above each ring to project on the replica when it is placed on that specific ring. The Hub then coordinates the activation (NFC on a Ring) and play (projection of a specific file via a specific Media node).

Festival of Britain Pink Knickers was a single interactive installation conceived, designed, and implemented over a 2-day creative workshop with curators. Connected to a display of women's

underwear, it invited visitors to explore the role of women from the 20s to the 80s as lived by individual women and as perceived by the society. In its aesthetic, the installation evokes a vanity desk with four drawers, each with cut-out paper doll dresses inspired by a decade that conceal NFC tags: a pair of underwear and a dress. A laser-cut woman silhouette on the desk (placed above a Ring) invites the visitor to dress the mannequin with the paper clothes: the underwear triggers personal stories while the dress represents societal changes. Videos are displayed on the screen hidden behind the mirror frame. (Figure 4)

Figure 4. (top) Four drawers on the vanity desk hold different decades (20s, 40s, 60s, 80s) and contain personal stories (underwear) and social changes (dresses) that, when placed on the mannequin play different videos (the 80s in the pictures). (bottom) Each cut-out has a NFC tag, a Ring is under the mannequin and a Media node connects to the screen.

Voices from the Past in Fort Pozzacchio complements a permanent collection of WWI artillery with the human side of the war, the emotional, personal stories of witnesses who had their lives affected by the presence of the fort. Besides the soldiers and the commanders, other stories are those of the engineer who designer the fort, the army chaplain, and the villagers before, during and after the war. Four thematic stations are positioned along the visiting route, each slot (a Ring) maps a personal story. At the entrance the visitor receives a 'pebble' that conceals an NFC tag and that, when placed on a slot, activates multimedia content. When leaving, the visitor returns the pebble, its NFC is read by another Ring that prints a personalised postcard with text automatically generated on the bases of the personal visiting path. (Figure 5)
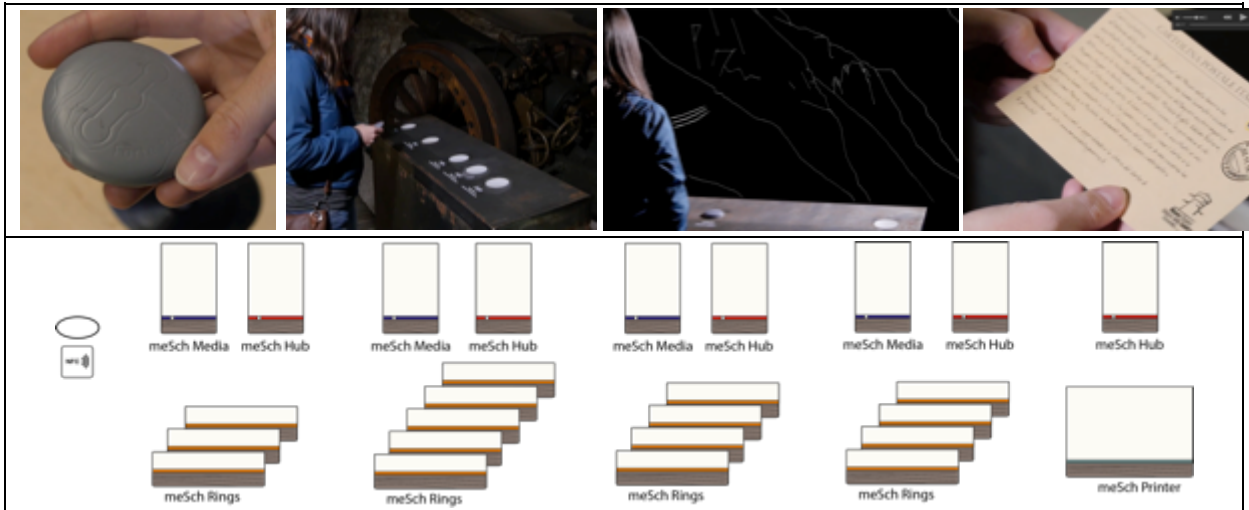
Figure 5. Voices from the Past in Fort Pozzacchio is a permanent installation. (top) At the entrance the visitor receives a pebble used to activate content at different station along the visit; when leaving the visitor returns the pebble to the desk and receives a personalised postcard with a summary of their visit. The pebble has an NFC read-write; each station has a set of Rings, one for each personal story, a Hub that controls the Ring and a Media node to project the content. At the exit another Hub controls the printing of the personalised postcard. The many Hubs are needed here as there is no WI-FI signal due to the harsh environment: a bomb shelter dug into the mountain.

The Hague and the Atlantic Wall was a temporary exhibition on the effect the construction of the Nazi costal defence system had on the city of The Hague (Marshall et al. 2016) (Petrelli et al. 2016). The same events were told by contrasting voices: the German soldier, the Dutch civilian, and the Officer who had to do the bidding of the occupiers against the population. Smart replicas of historical objects represented a voice and concealed an NFC. Ten display cases had an interactive Ring on which visitors placed a replica, then watched a video projected on the case and listened to the story via a earpiece. A final station printed a personalised postcard that gave access, via a unique code, to a personalised website where the visitors could contribute personal memories and explore those left by others. (Figure 6)
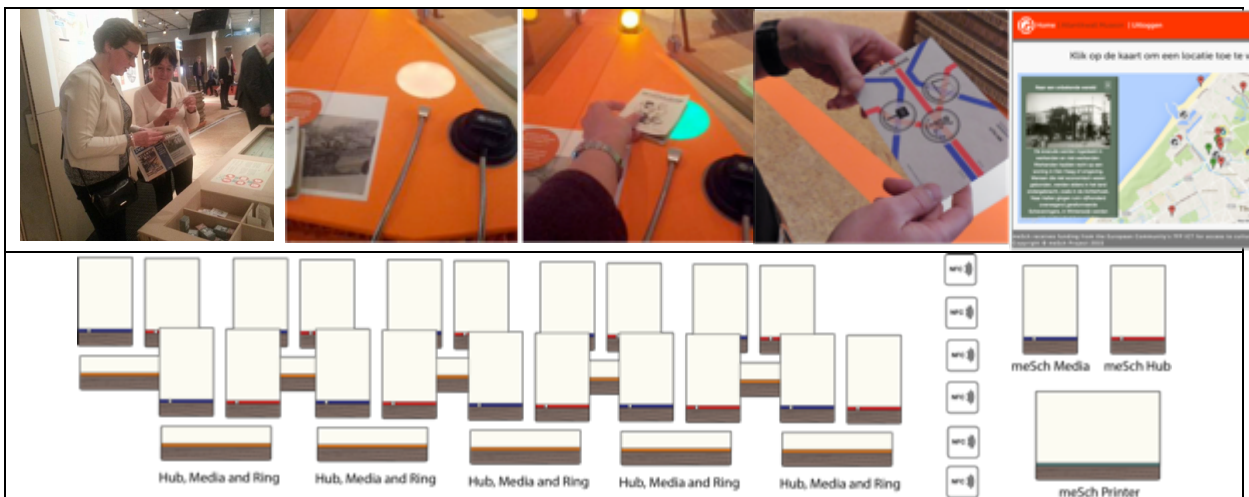

Figure 6. The Atlantic Wall: (top) (left) original objects and the replicas representing three different perspectives on the same historical events; (centre) the interaction at the case; (right) the printing of the postcard and the online interaction. (bottom) The replicas conceal NFC tags; ten interactive cases host a Ring, a Hub and a Media unit each; the printing station has a Ring to read the replicas, a Media to display instructions, and a printer for the personalised postcard.

My Roman Pantheon is, at the time of writing, in production and expected to be installed at a museum of Roman archaeology along Hadrian's Wall in January 2017[1]. It offers visitors an amusing way to engage with a display of Roman altars through the performance of a ritual that resembles customs at Roman times and provides information about the gods and religion. It consists of a temple where the visitor is greeted by Juno, queen of the Roman gods, and is given three gifts of light in a votive lamp. The visitor then enters the museum and offers the gifts to three gods / goddesses of his / her choice; however there are thirteen altars so he/she has to choose the three to whom they offer the lights to. On leaving, the offering lamp, now empty, is returned to Juno who rewards the worshipper with a personal oracle of the visitor's future at Hadrian's Wall based on the gods that have been honoured with the lights. Here the visitor carries the Ring while the gods / goddesses are marked with NFC tags. (Figure 7)
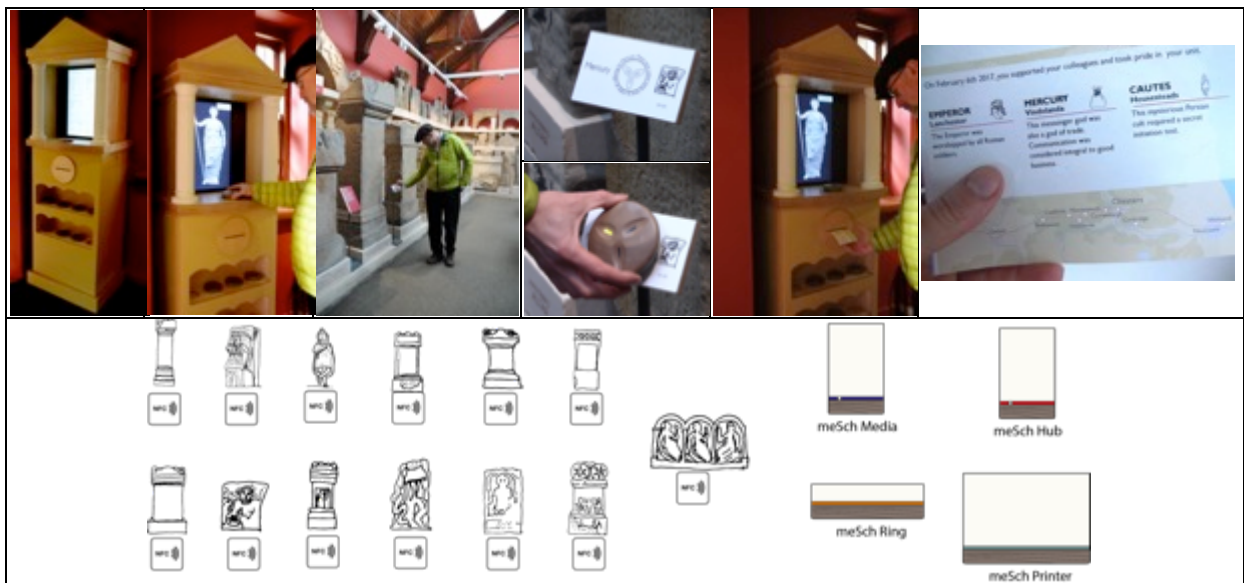

Figure 7. My Roman Pantheon is an installation for a small Roman museum. (top) At the temple, Juno charges the visitor's lamp with three lights, in the museum the visitor looks for the stands close to the altars of the gods and offers a light by swiping the lamp on the board, when the empty lamp is returned to Juno, the oracle is printed. (bottom) Each altar in the museum is marked with an NFC tag while the visitor carries the Ring; the temple conceals the Media node that controls the animation of Juno; the Hub controls the printing of the oracle (postcard).

The six examples above show how the same simple technology can be embedded in many different design creating different experiences. Each example was the outcome of a co-design and co-creation process (Petrelli et al. 2016b) never centred on the technology available. Indeed other very different interactions have been created as part of the meSch project using different combinations of IoT through the same cloud and online service infrastructure as in these examples (e.g. Augmented Reality (van der Vaart and Damala 2014), proximity sensors (Wolf et al. 2015)).

3. An Infrastructure for Digital Craftsmanship

The extended set of examples above shows how the same technology can be recombined to create very different experiences when designed around a specific museum / heritage sites. This flexibility is made possible by the meSch infrastructure that implements a version of Industry 4.0 (Hermann et al., 2016): it enables the rearrangement of components with minimal effort; uses standard for modular and distributed production; and collects use data via goods and services. Through meSch the different components communicate with one another to enable the bespoke rearrangement of the technology with minimal effort. The online services implement the modular and distributed

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[1] Should the paper be accepted, photos from the installed version will be used.

production that allows a dispersed team (i.e., in different EU countries) to collaborate: the museum creates the content with the meSch.io and uploads it on the Cloud, then the designers deploy the content in the IoT under development for testing. Finally by embedding NFC into objects handled by visitors it is possible to track their behaviour for further analysis of for offering new personalised services. The analytics of the visitors' data is particularly relevant in a perspective of Industry 4.0: fed back to the museum, log data empowers the museum to better understand the effectiveness of the exhibition and visitors' engagement and dynamically adapt to emerging needs.

With meSch, the designers take the technology for granted and focus on the specific experience: the contrasting voices on the same events, an emotional journey with witnesses of war, or the humour of becoming a Roman and seeking the gods' backing. The vision of Industry4.0 is to enable extreme customisation and the production of "batches of one". It is exploited here when designing for the specific. Key to this vision is the simplicity of use that fosters skills to effectively use the system to develop into tacit knowledge; the designers then engage at a deeper level with the specific problem and desires of the museum. This in turn creates new knowledge that can be shared with the community at large (via the meSch Share service) reviving the dynamics of the craftsmanship workshop in the digital age where expertise and skills are acknowledged and the perfectly crafted unique piece embodies values of quality and meaning (Sennett, 2008).

4. Conclusions

Digital is shapeless; as electricity, it needs a physical embodiment to be perceived (Kuniavsky, 2010) and the embodiment can be anything, i.e. a shape-changing wall that reacts to people's presence and behaviour (Yu, et al, 2016). Digital technology and information is a pliable material with unique properties such as enabling behaviours or keeping a state memory and changing it. Processing / delivering digital information is no longer the purpose of an object, but one of its many qualities (Kuniavsky, 2010). This is a shift of paradigm for interaction design: instead of designing a form around a set of functionalities, it is now possible to start from a concept and consider how it can be technically implemented only at a later stage. As new technology is invented and integrated with the emerging infrastructure of Industry4.0, designers aware of the possibilities offered by Cyber-Physical Systems, Cloud Computing and IoT can explore new creative spaces where digital and physical are combined seamlessly. As digital is neutral, the design exploration can expand in many different directions that use the same technological infrastructure, i.e new forms of publishing that combine digital content and material books; new ways to browse digital photo collections using personal bespoke devices. The vision is of aspects of Industry4.0 to become ubiquitous and available to designers for the creation of unique pieces that fit personal values, but that are powered by the same components.

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