3 Enabling the Masses to Become Creative in Smart Spaces

Orienting User Creation in the Internet of Things in the Context of the ITEA2 DiYSE Project

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Abstract In this chapter we present a first analysis towards the enablement of mass creativity in the Internet of Things, potentially leading to a wide range of new tangible, interactive applications that leverage the fundamental new possibilities of an emerging Web of Things. After an introduction of the socio-cultural practice of 'Do-it-Yourself' (DiY) as apparent in society, and a discussion on what DiY can mean for the Internet of Things, we introduce a typology of how people can potentially create and customise on top of the Internet of Things. Based on that, we elaborate three concepts forming a basis for new creation paradigms in such smart spaces, potentially leading to new DiY-enabling functions in Internet of Things service creation environments: the *Call-Out Internet of Things*, the *Smart Composables Internet of Things*, and the *Phenomena Internet of Things*. Next to a discussion of applicable state-of-the-art for implementing parts of these concepts, we show first experimental grounding for them, as part of the ongoing exploration process.

3.1 The Meaning of DiY in the Network Society

From the societal practice of DiY a lot of drivers and adoption models can be derived that may be applicable for similar people-driven creation in an Internet of Things world. In this section, we first look broadly at DiY as a cultural practice and discuss some core characteristics. We then make the transposition from the cultural practice to what this may imply for application creation and for context-aware environments, which are the necessary building blocks for reaching the goal of enabling the masses to become creative in smart spaces.

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3.1.1 DiY as Socio-Cultural Practice

Although nowadays DiY is commonly associated with youth subcultures, the origin of DiY as an activity can be found in the home improvement and decoration domain. Until the development of dedicated DiY stores in the 1970s, people who wanted to decorate, repair or modify their own home had to venture into the specialised world of the traditional builders merchant (Roush 1999). Companies making and selling tools and materials to amateur rather than professional customers undoubtedly were the promoters of the idea of DiY. In the 1970s lots of DiY shops and magazines were initiated. And this happened with great success. At the basis of the rise of DiY as a cultural practice were different drivers. Firstly, the economic changes brought that more people than only the rich part of the population had money to invest in home interior and decoration. Secondly, there was the fact that work hours became ever more expensive and the related rise of the DiY stores. But there are more than only these economical reasons that made DiY attractive. 'I want to do it myself' is one of the first sentences a young child uses, so it must be a very strong driver in humans in general. DiY confirms people's creative side, and gives them the feeling of 'being their own boss' (Hoftijzer 2009). DiY offers people pleasure by creating personalised artefacts or tune existing applications to their ultimate wishes. Leadbeater and Miller (Leadbeater and Miller 2004) researched another important insight regarding DiY. They claim that participation in gardening, sports and home improvement constitutes a form of everyday resistance to the alienating effects of contemporary society. The contemporary society indeed is characterised by excessive consumerism, globalisation and economic inequalities between persons and groups, alienating us from our environment and ourselves.

We can distinguish two stereotypical types of DiY-ers: the garage-DiY-er and the community-DiY-er. The first is someone who works alone, typically in a personal closed environment like a garage or attic, in a very dedicated way. The second can more often be found in a community of likely interested people. They collaborate in producing their invention of creation, so they are willing to make it public before it is finished and discuss about it with their companions.

We speak of DiY, but out of research we learned that less institutionalised channels, personal networks of family, friends and neighbours are crucial for individual experiences of DiY (Shove et al. 2008). People rely on the help of the so-called 'local warm experts' (Bakardjieva 2005; Steward 2007) or 'lead users' (Von Hippel 2005), terms which are defined in the context of domestication of information and communication technologies (ICT). In a way, DiY always has a *DiT* (Do-it-Together) component in it. Different authors invented names to refer to people active in DiY activities:

- Leadbeater invented the word 'Pro-Am'. A pro-am is an amateur that pursues activities out of the love for it, but at the same time setting a professional standard (Leadbeater and Miller 2004).
- Von Hippel proposed the word 'Lead-User'. A lead-user is at the leading edge of an important market trend, and so is currently experiencing needs that will later be experienced by many users in that market. She/he anticipates relatively high benefits from obtaining a solution to her/his needs, and so may innovate (Von Hippel, 2005).
- Levi-Strauss coined the word 'Bricoleur'. He describes the bricoleur as "someone who uses all the concrete materials he encounters in everyday life and all the earlier experiences of himself and others around him, to find solutions for the problems he is confronted with in everyday life" (Levi-Strauss 1968).
- Bakardjieva and Stewart invented the word 'local warm expert'. A local warm expert is "an Internet/computer technology expert in the professional sense or simply in a relative sense vis-à-vis the less knowledgeable other" (Bakardjieva 2005; Steward 2007).

With the attempt to describe the different roles and activities of a person doing DiY activities it becomes clear that a complex net of practices and social relations are at the basis of a DiY culture. These activities are also related to the kind of DiY activity people are executing; knitting pullovers, making a bench for a dog, designing an operating system, making a YouTube movie, and so on. But, overall, a DiY activity has some common characteristics. It is about *connecting*, about *taking control* and about *diversification*.

3.1.1.1 DiY is About *Connecting*

A core aspect of DiY is the act of 'creating' something. Gauntlett (2010) gives a good insight in the social aspects of creating. He distinguishes three ways on how making is connecting, and, therefore, in essence indicated that DiY is about communication.

1. Making is connecting because you connect things together (materials, ideas or both) to make something new.
2. Making is connecting because arts of creativity usually involve, at some point, a social dimension and connect us with other people.
3. Making is connecting because through making things and sharing them in the world, we increase our engagement and connection with our social and physical environments.

If we look at the changes ICT has brought today to the making is connecting paradigm of DiY, one can see that ICT has the potential of huge impact on DiY. The software culture is very much based on the reuse of code. The recombination of components and mash-up systems are other examples. The *Web 2.0* context made it possible for non-technical end users to create their own weblogs, web pages or *Facebook* profiles. The existence of online communities also is highly important for the DiY communities in the physical world. Not only can DiY-ers rely better on their local network for help, or people with the same interests, via these online communities, their community effectively gets world scale and world level, with *reputation* becoming a stronger factor.

3.1.1.2 DiY is About *Taking Control*

DiY is also about the power of mastering one's work and the tools one needs to succeed in achieving one's goal. Therefore, one needs capabilities as well as tools with particular attributes, *openness* being an important attribute of that. Or, like stated in the *Maker's Bill of Right* (Jalopy 2005): *"If you can't open it, you don't own it"*. In the Bill other important attributes of tools are mentioned that focus on handing over control to the creator:

- *Cases shall be easy to open.*
- *Special tools are allowed only for darn good reasons.*
- *Power from USB is good; power from proprietary power adapters is bad.*
- *Ease of repair shall be a design ideal, not an afterthought.*
- *If it snaps shut, it shall snap open.*

The aim of handing over the control to the creator or end user can be put in the discussions on innovation and technology. Paul Dourish (2006), in his design view, focuses on the fact that users are not to be perceived as passive recipients of predefined technologies, but as actors determined by the circumstances, contexts and consequences of technology use (Dourish 2006). Other trends that confirm the same 'taking control' view are the open innovation process (Chesbrough 2003), the mutual shaping of technology (Williams and Edge, 1996) and co-creation (Hoftijzer 2009).

3.1.1.3 DiY is About *Diversification*

As mentioned earlier, DiY can be perceived as the everyday resistance to the alienating effects of contemporary society. It can be seen as a reaction against excessive consumerism, globalisation and economic inequalities between persons and groups, which alienates us from our environment and from ourselves. While the globalisation makes every shopping street across a whole continent look exactly the same, the need indeed emerges for people to put forward, as an alternative to this 'more-of-the-same', something personal and unique that cannot be bought as a ready-made product in a store. Thus, DiY also is about diversification.

3.1.2 DiY in Software Application Creation

But to what extent is this DiY attitude, practice and culture already a real opportunity in the Internet of Things, as a driver for people to create their own applications in it? Own application creation can currently only be seen as an activity for the happy few. *iPhone* apps are still mostly written by small companies. Applications like *ZohoCreator* and *LongJump* are not aiming at end-users to create applications, but at an audience not much less but professionals. The role of open Application Programming Interfaces (APIs) for application creation cannot be underestimated in this respect, like it is a current topic in the context of *iPhone*, *Blackberry*, *Facebook*, *Twitter*, and other specific ICT environments.

3.1.3 DiY in Smart Spaces

DiY seems an important issue for the topic of context-aware systems and smart spaces. When Claeys and Criel (2009), among others, analysed the future vision on ambient intelligence, or ‘smart’ applications, two important issues were identified that point to the importance of personal creation of smart behaviour.

First, the vision on context awareness is very much technological driven and often does not take into account the meaning of context for the person that is acting in the particular environment. Since context is not something that describes a setting – *“it’s something that people do, the horizon within which the user makes sense of the world”* (Heidegger 1927) – it is not possible to define ‘context’ for every situation or for different persons at once. This problem lies at the origin of typical context-aware applications today being far from appealing. Because of these intrinsic characteristics, context cannot be defined as a fixed computational structure, and rather is an interesting but hard-to-capture concept.

Second, context-awareness seems to imply loss of control for the person it applies to. Much in contradiction to mostly all other applications, for context awareness there is often no such thing as ‘opt in’. While issues as privacy, autonomy and control were in the picture from the start, these issues seem very hard to address. As a result, users often don’t have any impact on the feedback loop (Crutzen 2005).

Both these issues are essential arguments for the importance of DiY in smart spaces. The aim is to make people again ‘own’ their own personal data and let them decide themselves how to use it for context–awareness at any time.

3.2 Research Orientation towards Tangible Creation in Smart Spaces

From the identified trends and drivers concerning the DiY phenomenon and its replications in the networked society of today, as pinpointed in the previous sections, the theme of user-generated – DiY – applications in the Internet of Things is still a very broad research area to tackle. As our multidisciplinary research methodology moreover involves *users* in the validation of mock-ups and proof-of-concepts as well as in the creation process itself, as active participants via e.g. *co-design* and *DiY 'kits'*, there is a need to organise the landscape in more precise creation paradigms for smart spaces, leveraging *tangible user interaction* for that purpose.

Therefore, as a 'landmarks' orientation in this landscape, we identified three architectural concepts that potentially are new enablers towards mass creativity in this area.

The final value assessment will follow from user feedback experimentation in the ongoing work, but already now these concepts can help confining the problem area. In turn, this will make the actual analysis of their potential merits and technological feasibility more practicable. Concrete experimentation around the concepts therefore does not need to resort to one very narrowed-down application domain a priori, but can rather try to apply the concept in multiple concrete domains to enrich it generically, without ending up in an explosively broad DiY scope.

So, in the following sections we discuss the three candidate enabling concepts and add first experimental grounding to them:

- *the Call-Out Internet of Things,*
- *the Smart Composables Internet of Things, and*
- *the Phenomena Internet of Things.*

However, first, as a basis, we introduce a typology of what kinds of DiY creation are imaginable in smart spaces. While acts of DiY show to have an important potential in the Internet of Things, as discussed previously, we should indeed first identify what these DiY creation acts could be in this context. As illustrated by Figure 3.1 below, we can at least distinguish three different, but highly interrelatable areas for this, as a course typology for DiY creation in the Internet of Things:

- First of all, having a large network of interconnected sensors (and actuators) principally allows for people to incorporate the related data streams in their *DiY applications* that *'use thing data'*. Today, several examples of that exist in the web, as we will discuss further on.
- Secondly, an act of DiY can clearly exist in people *connecting up new sensors* (and actuators) to the Internet of Things, as a form of *DiY installation*. Here

also, several examples exist today, e.g. in sensor network-enabled smart homes, though this is often offered via technologically closed solutions.

- Finally, the ultimate tangible creation experience is deriving from the current trends in DiY electronics, where augmentation and composition as an act of *DiY building smart objects* has become technically feasible. As such, people can be creative in shaping the tangible interaction front-end to the Internet of Things.

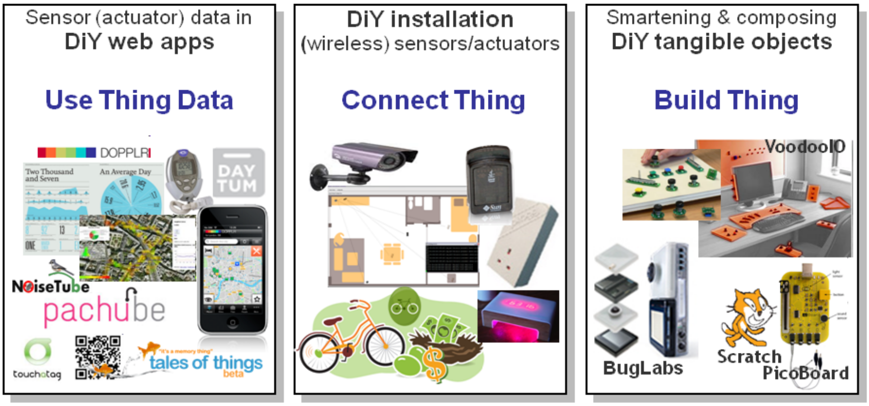

Fig. 3.1 Typology of DiY Creation in the Internet of Things

Inspired by this course typology, in the following sections we formulate three candidate concepts that could enable creativity on top of an Internet of Things.

3.3 Candidate Enabling Concept 1: The Call-out Internet of Things

We define the concept represented by the term *Call-Out Internet of Things* as entailing that the network – or cloud – gets the capability (for people) to expose and exchange call-outs in the user surroundings, as a means to provide individual users and communities with a locative, distributed communication with objects in the environment, and through this, with peer users and communities.

Call-outs, as meant here, may entail the traditional variety of information properties of locations, objects or other aspects of the surroundings, but especially can also be *behavioural descriptions*, describing a local interaction pattern, implying requests for interaction and an opportunity for adding new elements or actors in an open-ended machine or process. A Call-Out Internet of Things would, moreover, support the exchange and reuse of these properties across contexts of place, time or embodiment.

While examples of implementations exist that fall under this definition of the call-out concept, we use it as an instrument to get a deeper understanding of it as a new medium in ambient experiences. Thus, in this section we discuss how this concept is currently applied and what we see as future challenges in mass creativity in the Internet of Things from this perspective.

In fact, call-outs are commonly known in our culture already and are used in a variety of communication applications. People can experience call-outs as a communication medium in their own intimate social space as well as the broader public surroundings. Call-outs have the potential to be used for exclaiming aloud and with surprise, e.g. emotions and feelings, or can be used to post triggers and challenges to other people. For example, commercial electronic billboards in city shopping streets are competing to get their messages across. The call-out balloons in comics, depicting dialogues and supporting the structure of the narrative, are another effective example of attention-grasping communication. As early as in the Middle Ages, Leonardo da Vinci masterly practiced the technique of adding text captions to complex drawings and sketches to explicitly communicate on innovative compositions. In this case, we can see call-outs as a way to expose otherwise hidden meaning and insights into structure. Even today Leonardo's style keeps triggering people's imagination, as illustrated by numerous *Exploded View* drawings or *Cutaway View* drawings available on the Internet. An example is the Leonardo da Vinci styled exploded phone drawing by which artist Kevin Tong captures the imagination of H.G. Wells and the brilliance of Jonathan Ive[20].

In the networked society of today, at least three types of call-outs are practiced. Below, we distinguish roughly three families, using the technological means leveraged for thing/place identification as a categorisation:

- *location-based call-outs*,
- *tag-based call-outs*, and
- *image-based call-outs*.

3.3.1 Location-based Call-outs

Since geo-mapping technologies emerged to be at the disposal of the 'creative' lead user communities, all kind of geographical maps get augmented with layers of personal and community driven annotations, typically as pin-style call-outs. These personally, culturally, and socially driven reflections and annotations augment locative meaning and stimulate interaction in this way. In fact, the Earth's surface is becoming a distributed drawing canvas where people can stick their scribbles on, as a huge, locative mind map.

[20] http://www.isteamphone.com

Google Maps and *Google Earth* applications are used to develop map-based applications which map call-outs in virtual layers depicting locative interactive media. The *Augmented Reality* (AR) browser *Layar*[21] is a good example, where people can browse knowledge layers in overlay to the camera view, position-based. In this way, knowledge attached by people – or commercial organisations – can be experienced in its real geo-spatial context by others, giving the environment new collective meaning, e.g. triggering other people's recollections. With Layar, users can also be routed to locative points of interest by means of 'radar' functions, as a new form of searching. An interesting Layar layer is the application *Tweeps Around*, which queries Twitter for posts labelled with an exact location[22]. With this example, the link to social networks is indeed made, hinting at a trend towards much richer geo-aware variants of the popular communication means. Another currently popular example of that trend is in fact *Foursquare*[23], where people earn community recognition and sometimes rebate vouchers by *checking-in* often, in particular venues such as public places, restaurants and other points of – often commercial – interest, having the community comments at the place as call-outs.

Wikitude World Browser is yet another example of an AR browser, leveraging a location-based style of Wikipedia[24]. A lot of creative development activities are organised and supported, fostering open and collaborative development by the masses extending the Wikipedia-style spirit to a location-based experience. *Wikitude Drive* is the first mobile AR satellite navigation system currently being trialled.

As seen in the examples above, the attachment of crowd-sources data to specific locations in the surroundings by means of rich media overlay of call-outs on geographical maps, by this augmentation making the space 'smart' and communicative in a particularly locative way, is showing to become really valuable since a few years. It is no surprise that open creation platforms, even commercial ones, are now emerging which leverage this 'local value at global fingertips'; an example of such a platform is Google's *AR Wave*[25].

3.3.2 Tag-based Call-outs

Another technique for realising call-outs is to explore the augmented space by means of physical tagging technology, inspired by the human touch paradigm – an act which in itself is again sensationally and emotionally relevant in the user ex-

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[21] http://www.layar.com

[22] http://squio.nl/projects/tweeps-around

[23] http://foursquare.com/learn_more

[24] http://www.wikitude.org

[25] http://arwave.org

perience. Historically, this was one of the first expressions of the emergence of an Internet of Things.

Here, the key is that the physical objects are approached at short distance – touch – and that access to augmented media is achieved by reading an attributed object identifier. The reading can be visual, such as one-dimensional barcodes and many variants of so-called *QR codes*, or is done by means of short range radio communication, often *Near Field Communication* (NFC) using *Radio Frequency Identification* (RFID). Today, user support for managing online identifiers and the associated media is offered via various online portal services, such as *Thinglink*[26], *Tales of Things*[27], *ThingD*[28] and the *Touchatag*[29] platform, which pioneered the RFID tagging scene and now offers both business-to-consumer (B2C) as well as business-to-business (B2B) interfaces, e.g. for payment applications.

3.3.3 Image-based Call-outs

One can even go further and use image recognition as the way to identify objects or people in the surroundings, without any further explicit tagging technology. Examples are

- Google's *Goggles* initiative[30] which can visually identify objects[31] as well as recognise text, and
- the Augmented ID technology in the *Recogniser* application of TAT[32] which associated a person's social network and other information with a person's recognised face, in a handy overlay to the image.

3.3.4 The Future of Call-outs

From the examples listed above, we see that call-outs are indeed getting established as a new global, locative interaction medium. It is reasonable to assume that the applications and technologies will evolve to have a conceptual common de-

[26] http://www.thinglink.com/

[27] http://www.talesofthings.com/

[28] http://www.thingd.com/

[29] http://www.touchatag.com/

[30] http://www.google.com/mobile/goggles/

[31] In order to avoid privacy issues, Google decided to remove the face recognition feature from Goggles shortly after release.

[32] http://www.tat.se/

nominator as an enrichment of our augmented environment. Moreover, with the mixing with social network effects, as seen in several of the mentioned examples, we can expect that locative space will be shaped by DiY creation acts by the masses. Could we say that 'space and place innovations will be democratised' or could we speak about emerging 'Von Hippel' places and spaces[33]?

Even when confining the research space to the identified area of the Call-Out Internet of Things, a number of fundamental research questions remain to be investigated with respect to the enabling concept's meaning and future evolution:

- Will call-out technologies effectively empower people to create any kind of informative knowledge communication *beyond the augmentation by means of classical multimedia*, for example by controlling *haptic feedback* embedded in spatial experiences through, e.g., locative twittering?
- Will people effectively go *beyond the single-point locative augmentation*, towards more composite use of multi-point space, or ad-hoc mind mapping?
- What is the relation between the *tangible object's lifecycle* and its augmented virtual arguments?
- What is the role of call-outs with respect to an *object's intrinsic history*? (See in this respect, e.g., mixed-digital-and-physical-environments[34]).

Finally, can call-outs become a way to pinpoint instructions for acting, or even computing? This gives rise to the concept of the *Smart Composables Internet of Things*, as discussed in the next section.

3.4 Candidate Enabling Concept 2: The Smart Composables Internet of Things

The concept represented by the term *Smart Composables Internet of Things* can be defined as a specialised instance of the Call-Out Internet of Things concept, focusing on knowledge support for a – DiY and industrial – *(de)composition, production or recycling of physical objects*. In a Smart Composables Internet of Things, everyday objects get augmented with crowd- or industry-produced *instructions* and how-to's concerning how they have been or can be produced and composed and how their parts can be reused in other combinations, also in combination with other objects.

Querying can be done by context, possibly in relation to *Phenomena* (see later section on the *Phenomena Internet of Things* concept) and the context of surrounding objects, e.g. with call-outs resulting from Phenomena about frequently used combinations, or nearness of other objects with which known combinations

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[33] http://web.mit.edu/evhippel/www/

[34] http://www.slideshare.net/nicolasnova/designing-a-new-ecology-of-mixed-digital-and-physical-environments

exist. A related classification of smart objects based on their awareness, their representation and their interaction can be found in Kortuem et al. (2010).

3.4.1 Object Classification According to Creator and Purpose

Our model in Figure 3.2 arranges smart objects according to their creator and purpose. Sometimes the *creator* is an individual creating an object for personal use, while in other cases the creator is an industrial actor who creates objects for mass consumption. In the figure below, we denote this as *self-made* and *ready-made* smart objects, respectively.

The *purpose* of a smart object may be to play a role in any application – or at least in a broad range of applications – or it may serve as a component in one specific application. We call this *open-ended* versus *specific* smart objects.

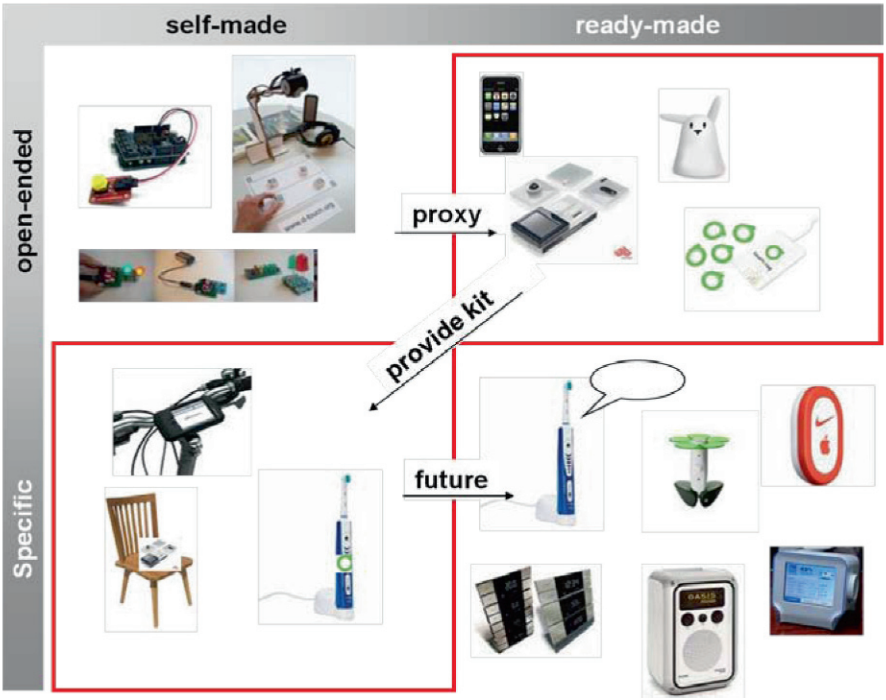

Fig. 3.2 Smart Objects Classification According to Creator and Purpose

Figure 3.2 is filled with today's examples of smart objects. *Littlebits*[35], in the upper left quadrant, is an example of a smart object that can be created by an individual through combination of different electronic components with the purpose of creating any application that the person can think of. In the opposite quadrant, lower right, we see examples of smart objects that are created by industry for a specific domain. *Chumby*[36] is an early example of such a smart object connected to the internet, with applications such as morning wake up calls as well as serving as a window to your favourite social networks.

However, the two most important quadrants for the discussion in the Smart Composables Internet of Things are the upper right and the lower left categories[37]. The *BUG*[38] is an example of a ready-made, open-ended smart object, consisting of a modular hardware kit, out of which individuals can create standalone smart objects by combining kit parts. The BUG can, however, also be used to augment an everyday object for a domain-specific application, thus moving to the lower left quadrant of the diagram. An example of such an augmented object that is self-made for a specific goal, is a chair equipped with the BUG components, for example to detect whether a person is sitting on it or not. The BUG components in such case could, at the same time, be used to, for example, provide the person with an auditory feedback when someone rings the door.

Composables are the smart objects in the upper right quadrant of our diagram. Their strength lies in the creativity that they give to individuals to compose or decompose, and to connect and disconnect with materials, people and society. Although composables are open-ended, they can be components of a *domain-specific kit* that supports the user to create domain-specific smart objects.

If networks of composables exchange data by means of sensors and actuators, according to the Smart Composables Internet of Things concept, their context of use needs to be known in order for anyone to understand what this object interaction means. It is exactly the *sharing* of call-outs that promises to bring support in this respect, attaching meaning to the smart object as well as the data exchanged by it, after *'installation'* as well as during *(de)composition* of the smart object.

Beneath this *user-level* meaningful exchange of data between located, identified objects and object parts, also the *technological* means are needed to do the actual data exchange. Such 'physical mash-up' at the technical data exchange level is typically done via web interfaces. Currently, there is a tendency to consider a REST (Richardson and Ruby 2007) mechanism in this respects, resulting in the

[35] http://littlebits.cc/websiteV1/

[36] http://www.chumby.com/

[37] Note that in this classification we see that object that offer a web-accessible API are sometimes classified either as *open-ended* or as *specific*. This is judged according to their openness for integration in a physical smart object design, as discussed here. So, although classified here as *specific*, for objects such as the Chumby there is nevertheless *another* degree of openness, because of the potential to use – or 'misuse'– them via an API for other applications than originally intended by the manufacturer.

[38] http://www.buglabs.net/

tentative definition of the *Web of Things* (WoT) as a web of bidirectional *RESTful* data exchange between objects (Guinard et al. 2010; Guinard et al. 2009).

3.4.2 Grounding via Experimentation

For the purpose of experimentation grounding of the Smart Composables Internet of Things concept, we organised a workshop with five researchers, starting from four use cases with associated mock-ups of domain specific, self-made composable-augmented objects. All four use cases were based on the use of the same sensor (a greyscale vision sensor) and one actuator (a dispensing actuator). The basic idea behind the experiment is to experience how the act of building such object would proceed, building a 'quick-and-dirty' mock-up of it, and how meaning could be attached to it. The chosen example mock-up cases were inspired by small real-world problems, which we formulated as design goal questions from the user perspective:

1. *The duster case*: how would people create a duster that detects spots on the floor, and automatically cleans them up?
2. *The door case*: how would people augment a door to sprinkle a nice fragrance in the room, whenever the door is opened?
3. *The plant case*: how would people create a flowerpot that automatically provides the contained plant with the right amount of water – in time, and without any manual human intervention?
4. *The garage case*: what can people build to avoid that fresh oil spots in their car garage make their shoes and carpet dirty?

Common to all cases was that we assumed a base object with an initial function (a door is used to close a room, a duster is used to get rid of dust, etc.), to be transformed into a smart object by combining them with composables, adding the additional functionality. The following figures show the artefacts resulting from the mock-up exercise.

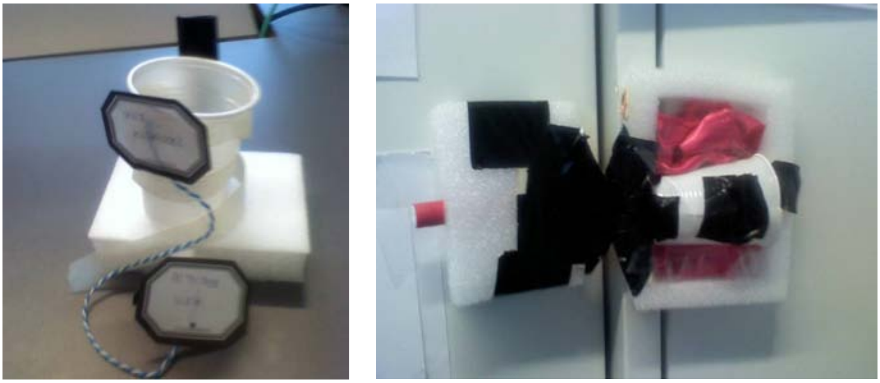

Fig. 3.3 Mock-Ups of a 'Smart Duster' (*left*) and a 'Fragrance Spraying Door' (*right*)

As shown in the left picture of Figure 3.3, one experimenter augmented the duster by attaching the vision sensor to the front of the tool foot, labelling it with a sticker reading 'you are a spot detector', and attaching the dispenser to the duster stick, labelling it with a sticker reading 'you are a spot cleaner', hinting at this approach as a non-technical, DiY way of designing the desired functionality.

The right picture in Figure 3.3 shows composables as attached to a hinging door side by another experimenter, with the vision sensor this time applied to detect the status of the door (i.e. open or closed), and a pink knob representing a fragrance capsule inserted in the dispenser.

The left picture in Figure 3.4 below shows the resulting smart plant pot mock-up, for which the experimenter chose to assume one composable as a platform for the pot to bear a humidity and other sensors as well as a spraying composable hanging over the plant, and to aggregate the sensor data processing, potentially connected to a processing back-end in the network. Again the meant functionality is simply indicated by 'call-out' stickers.

Finally, the smart oil cleaner mock-up is shown in the right picture of Figure 3.4. Here, the experimenter conceptualised an autonomously driving platform for pluggable composables such as the oil stain detector and a sawdust dispenser, the platform having the same sensor data connection and aggregation function as with the smart plant pot.

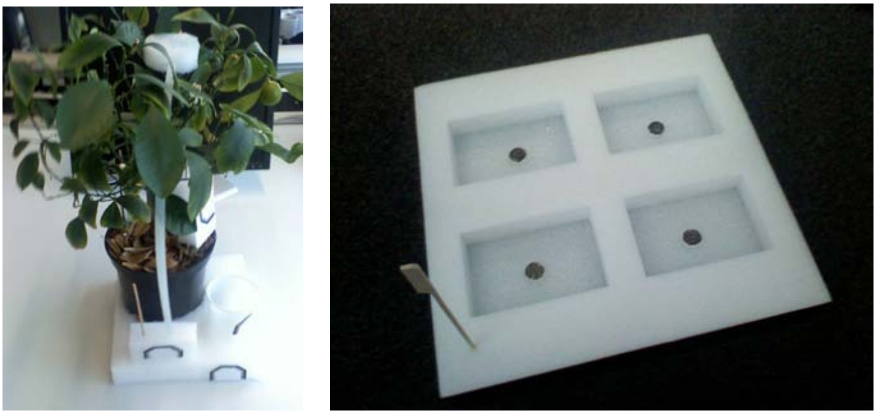

Fig. 3.4 Mock-Ups of a ‘Smart Flowerpot’ (*left*) and a Smart Oil Cleaner (*right*)

By observing how the experimenters approached the creation process, and the choices they made to get to the specific tangible results they created, the smart object mock-up experiments teach us that there is no single way to give functions to smart objects by means of augmentation with composables. The stickers that some experimenters used for labelling and giving meaning to particular composables or the composed whole, indicate various ways how software or call-out technologies could be used in real smart objects as would be composed by non-technical, kit-supported creators. The notion of a physical platform that makes composable easily pluggable, as introduced in two of the mock-ups, may offer a new approach for the practical implementation of a particular type of *composition* call-out.

3.5 Candidate Enabling Concept 3: The Phenomena Internet of Things

The basic concept as defined by the term *Phenomena Internet of Things* is that the network – or cloud – gets the capability to capture ‘phenomena’ in the user data, as a means to provide individual users and communities with feedback on patterns in their personal daily life, or in the broader society. Of crucial importance in this respect is which patterns are of real value to users, implying that close user involvement in the iterative identification of these phenomena is essential for maximising the potential of adoption in user-generated or other applications. So, in the *Phenomena Internet of Things*, higher abstractions of user context-awareness, considering long-lived patterns in personal life and society, are aimed to be derived from crowdsourcing across user groups, geography or application domains.

Of course, the crucial question in this perspective is: *Which patterns are of real value to users?* In other words, essential to the identification of these – probably also reusable – patterns is that *users are closely involved in the identification process, iteratively pointing out individual appreciations of proposed patterns*. From that, Phenomena can be identified by the crowd, in line with the continuing *crowdsourcing* trend (Howe 2006), searching such relevant patterns by leveraging massive dimensions of scale, over long time spans, within or across geographical locations and in different application contexts. This Phenomena effect is in particular strengthened by the growing amount of personal data becoming available in the Internet of Things.

3.5.1 Ingredients of the Phenomena Internet of Things

As essential aspects to a Phenomena Internet of Things, we distinguish four 'ingredients' that need to be leveraged in order to obtain valuable Phenomena enablement:

- massive data *collection*,
- user inspection and appreciation *feedback*,
- relevancy improvement from *iteration* on captured feedback, and
- fuelling user-generated *applications* with Phenomena.

In the next subsections we shortly discuss each of the four ingredients.

3.5.1.1 Ingredient 1: Massive Data Collection

The emergence of the Internet of Things and the linking of this swarm of sensors and actuators to the open web, for use in user-generated applications, with examples like *Pachube*[39] and *Noisetube*[40], in combination with the vast range of 2.0-style, crowd-oriented application (and content) creation tools, programming interfaces and application stores, is indeed facilitating a world in which a massive data collection is put to use for individual users as well as society.

In an example such as Noisetube, massive data is collected due to large numbers of people contributing their personal mobile noise measurements.

Clearly missing in this emerging Web-of-Things, is a collective identification of valuable, abstractable patterns, *Phenomena*, which could trigger much richer application possibilities, in the least already because *many such potential patterns are simply not recognised yet as valuable elements for influencing the behaviour of (newly created) applications*, at various expertise levels of the creation process.

[39] Pachube, http://www.pachube.com/

[40] Noisetube, http://www.noisetube.net/

Another example is the data collected through detection of user activities in a smart house, with for example hourly, daily or weekly repeated patterns becoming apparent over long time spans.

3.5.1.2 Ingredient 2: User Inspection and Appreciation Feedback

Irrespective of whether users provide data consciously – e.g. by using a sensor explicitly, to measure something in a specific context, or by manually entering such measurements – or unconsciously – e.g. by giving consent to track geographical position, or to automatically detect nearness or touch in an enhanced environment – users should at all times be able to *inspect, control* what data is collected, and *restrict* use, according to varying types of constraints, as identified also as crucially important in Greenfield's *Everyware Theses* (Greenfield 2006). However, as seen in many dedicated applications in the past, the occasional user – in contrast to the 'data organisation fanatic' – needs really simple ways to impose this control (Dey et al. 2006; Claeys and Criel 2008).

Therefore, a sound starting point may be a system defaulting to an assumption of all data being strictly personal and only for personal use, further only requesting user intervention upon specific pattern proposals instead of demanding the configuration of controlling rules for the entire space.

Incentives for the user to get involved in such eased participation can be:

- simply the comfort of visual representation of the data, and standard trend analysis of it, possibly leading to the user's enthusiasm, discovering trends personally perceived as relevant in the analysis of own, community or environmental behaviour over time and place, as well as
- the reuse of such enriched data triggers in personally created, community-built or existing applications.

So, as examples of forms of user feedback one can think of

- users making a personal selection of conventionally analysed data trends or specific data representations in a visualisation application,
- users formulating particular thresholds or other data conditions as trigger for certain application actions,
- users giving simple means to indicate approval or disapproval of application behaviour,
- or still any other form of appreciation feedback.

3.5.1.3 Ingredient 3: Relevancy Improvement from Iteration on Captured Feedback

The key ingredient that should make Phenomena different from unidirectional data mining is indeed the *closing of the loop*, allowing *controlled amplification and re-confirmation by users* on what data and data patterns are increasingly relevant, in general or in particular cases. From this massive re-iteration on user appreciations for captured data as well as preferred filtered/mined visualisation options, *popularity of reoccurring patterns,* as *Phenomena*, can be analysed. The identification of the most relevant patterns as candidate Phenomena even allows for the crystallisation and optimisation of them into *new enabling data brokerage and exposure functions*, that can become new services or products for actors that want to engage in a business based on the Phenomenon.

For example, from the previously listed means for user appreciation feedback, if many of the most popular visualisations as chosen by users are invariant to particular parts of the collected data streams, this may mean that indeed that part of the data is less relevant in general. Or, patterns that support application behaviour that is systematically approved, respectively disapproved by users, may grow, respectively diminish, in importance as candidate Phenomena.

3.5.1.4 Ingredient 4: Fuelling User-generated Applications with Phenomena

In most currently available tag correlation services, the one-to-one relation between tag reading events and web links is the key service value, such as in many of the example web services previously discussed under the section on Call-Out Internet of Things. In contrast to that, a second important incentive for users in leveraging new Phenomena – whether still emerging in a Phenomena network, or already institutionalised in a brokerage service – lies in *applying a Phenomenon in an application*. Either the awareness for the Phenomenon through its use in the application, or the entire application by itself, is then discovered or user-generated. In this way, an additional wave of user value emerges from the identification of the Phenomena.

Many of the existing context-aware applications can be seen as canonical examples of Phenomena-triggered application behaviour.

3.5.2 Links to Current and Historical State-of-the-Art

Although in literature the term 'Phenomena Network' was used for event tracking in Wi-Fi network topologies (Bose and Helal 2008), the concept as we have defined above goes beyond what was once applied in particular domains already.

In plain mash-ups[41], the ‘Phenomena Network’ is restricted to the user profile stored as cookies and preferences in the web browser. In the domain of assisted living, several research activities tried to track user activity over time and monitor health, often assuming a given scenario (a classification task), or analysing specific sequences (a time series analysis task). In the vast amount of literature on computer vision for activity recognition (Moeslund and Granum 2001), motion patterns include variations of neural networks and hidden Markov models. An intensive area of research is the area of smart homes[42,43,44,45], where contextual information is gathered from many different kinds of sensors around the house or office, often also using (layered hidden) Markov models, naive Bayesian networks, or decision trees to identify particular context situations (Desai et al. 2002; Isbell et al. 2004). In the domain of wearable and mobile computing, principal component analysis, Kohonen self-organising maps, k-means clustering, or again first order Markov models are used to detect user status from wearable sensors (Oliver et al. 2002; Krause et al. 2003). Finally, some original approaches use an ontology, e.g. extracted from *WordNet*, to mitigate the problem of activity model incompleteness (Korpip et al. 2003), or use other crowdsourcing techniques to derive an activities vocabulary for unsupervised activity recognition (Munguia-Tapia et al. 2006; Perkowitz et al. 2004).

While closing the loop with users iteratively providing appreciation feedback on identified patterns has already been considered for many applications in the pervasive or ubiquitous computing domain, the more generic approach of leveraging this *Ingredient 2* to identify *Phenomena*, is only starting to be analysed for its potential.

In fact, the personal data analysis aspect in this concept is recently also studied in the new field named *‘Personal Informatics’* (Oberkirch 2008; Jones and Coates 2008) with services like *Dopplr*[46], *Fire Eagle*[47] or *Daytum*[48]. These new services, however, do not offer a higher pattern abstraction level, as a commonality for many, and so leave it entirely to the user how to interpret the data in various visualisations, often even exclusively oriented to visualising long-term data trends, without any real-time applications.

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[41] Many examples of mash-ups are collected at http://www.programmableweb.com/mashups

[42] The Adaptive House. http://www.cs.colorado.edu/7Emozer/house/

[43] The Aware Home. http://awarehome.imtc.gatech.edu/

[44] Easy Living. http://research.microsoft.com/easyliving/

[45] MavHome, Managing an Adaptive Versatile Home. http://mavhome.uta.edu/

[46] http://www.dopplr.com/

[47] http://fireeagle.yahoo.net/

[48] http://daytum.com/

3.5.3 Potential Application Domains

In the following subsections, as further illustrations to the concept, we shortly discuss two example application domains where the Phenomena Internet of Things concept could enable new, improved-behaviour applications.

3.5.3.1 Home Applications Aware of Personal Context

In the domain of personal-context aware smart home applications, we consider the example of ‘programming’ the home atmosphere by means of the most appropriate selection of background music and lights ambiance. In such an application, the user ideally would like the system to ‘understand’ which different personal atmospheres– ‘My Atmospheres’ – should be distinguished, and what music and light actions should be taken upon that. In a classical approach, such an application would require the user to configure, or even design a complex set of context rules, triggered by carefully chosen conditions, and resulting in a well-structured sequence of actions. Crucial for the Phenomena Internet of Things approach thus is that this configuration complexity is hidden from the user dramatically better, by deriving an internal set of rules, conditions and actions, *indirectly rather than explicitly* based on appreciation feedback of the user.

In a first step, the user would assist in monitoring his/her own behaviour at home, e.g. by recording the interactions he/she consciously or unconsciously makes with tagged or otherwise smart objects around the house, possibly by means of DiY augmentations.

From the monitored activity, which may already be tailored by the user to contain especially relevant clues, new patterns are mined, correlating them with (initially) manual lighting and music selections.

When candidate Phenomena are detected, they are presented to the user as a new or clustered candidate ‘My Atmosphere’, with a matching proposal of a particular music cluster or lighting characteristic.

As a crucial step in the iterative process, the user can start naming the proposed atmospheres, potentially promoting them to effectively become a (possibly temporary) ‘My Atmosphere’. The user not only becomes aware of the underlying patterns the system discovers, but also implicitly appreciates their relevance from the personal user perspective.

While iterating in this way, the system gets to know what underlying Phenomena best trigger or determine the personal home atmospheres, and gets to know which atmospheres the user indeed confirms to be representing a concept in the user’s mind.

Also by detecting the user’s activity to explicitly *deviate* from the regular activity patterns in presumably active atmospheres, for example, the system matures to become more and more reliable, without, at any time, taking away user control, and, at all times, allowing him/her to use this control to eventually steer the desired light and music settings as of a selected atmosphere.

Beyond that stage, users have at their disposal a well-trained system that detects and possibly even predicts personally defined atmospheres, which they now can start leveraging in other smart home applications, like presence-based communication applications or home energy management services. From use of the data in these additional applications, new types of user feedback, yet refining the personal atmosphere model, can follow, making the system still more accurate.

3.5.3.2 Massive City Data for 'Optimal' Traffic Behaviour

A totally different application domain, yet allowing also for applying the Phenomena Internet of Things concept, is the domain of multimodal (public transport, cars, pedestrians, bicycles, etc.) traffic optimisation in urban realms, leveraging large amounts of Internet of Things flow data.

Here, the process starts with the classical analysis of crowd traffic patterns and visualisation of them in an attractive way on geographical maps for citizens. Phenomena, in this context, could be public phenomena concerning e.g. the behaviour of the crowd transport activity, in the occurrence of particular local events (accidents, road blocks, etc.), changing weather conditions or still other conditions. Based on these, a routing application could derive route change advice to users, and get feedback by people actually following the advice or not, or giving other appreciation when an advised route is eventually followed.

In this way, a model is grown about the collective awareness and behaviour upon changing city traffic conditions. From the user feedback, the system learns what traffic phenomena are relevant to people, making them change route plans, or it learns about obstructions it did not explicitly detect in the first place (very local peak hour traffic congestion effects, unregistered road works or damage, etc.).

Here again, other applications can start using the identified Phenomena as advanced context triggers for smart adaptation.

3.5.4 Grounding via Experimentation

In the context of the Phenomena Internet of Things concept, we started an experiment supported by the City SensPod sensors[49] – as also used in Fing's Villes 2.0[50] project – with the ultimate goal to demonstrate an example where citizens co-produce overall city environmental data, consequently finding themselves em-

[49] Sensaris, http://www.sensaris.com/

[50] La Montre Verte, http://www.lamontreverte.org

powered to change their own ecological behaviour. In this way, the citizens also influence decisions and actions of local government and other stakeholders. In fact, in line with the notion of *Phenomena*, the community's *Situational Awareness* (Endsley 1995) is increased. Figure 3.5 shows the City SensPod – packed with an extendible set of sensors for noise, metal oxide, humidity, COx, NOx and GPS location – and illustrates that raw data, which is obtained via Bluetooth.

With the experiment we target large scale experimentation in the city for

- obtaining citizens' feedback, observing the changes in their behaviour, as well as possible promotion of social actions upon getting a city view from the data; and
- evaluating the platform for (anonymously) collecting data and deriving patterns from it, to be identified ultimately as *Phenomena*, and to be applied in user-generated applications, e.g. for 'green route' navigation.

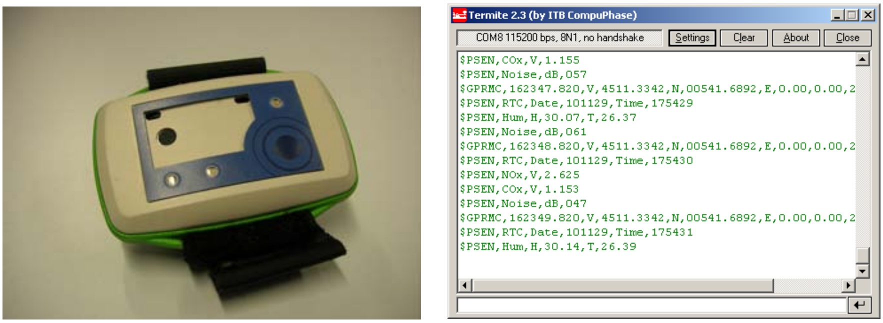

Fig. 3.5 City SensPod and an Impression on Raw Data Collection

The Prototype System
From the target goals stipulated above, we built a first working prototype in an initial technical step towards the evaluation of the Phenomena Internet of Things concept in a user community.

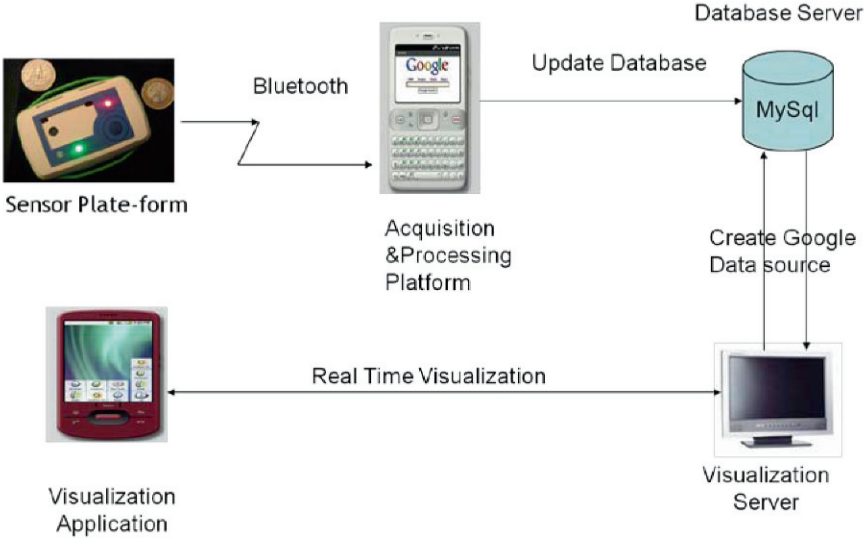

Fig. 3.6 Phenomena Prototype Architecture

As depicted in Figure 3.6, we mounted the City Senspod device to a PC via a Bluetooth connection, on which we implemented a simple acquisition and parsing service, allowing a developer to quickly parse any event coming from the device and transform it into a *tuple* of type *{Measurement Timestamp, Measurement Type, Measurement Value}*. The stream of *tuples* is saved at a remotely located *MySql* database, from which real-time visualisation or any – possibly third party – application is made possible using a Google visualisation API, taking the *MySql* server as an external data source.

Currently, it is still up to the developer to design and make his/her own visualisations. For instance, as shown in Figure 3.7, we implemented a real-time, online visualisation of noise data. The visualisation on the right in the figure shows a more sophisticated instrumentation, allowing users to selects parameters according to their preferences.

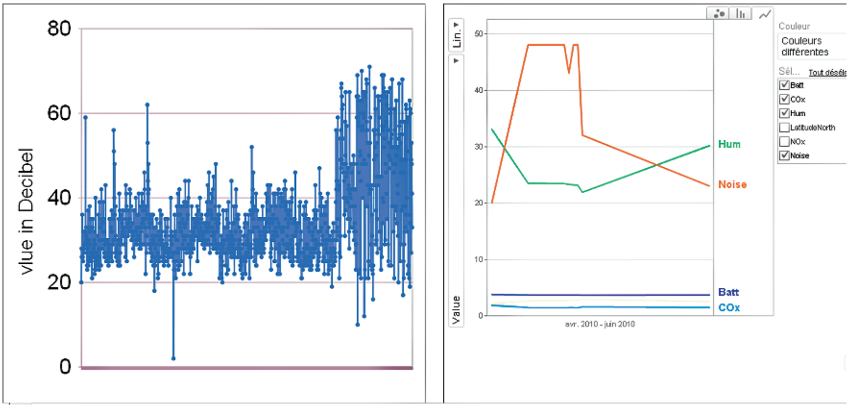

Fig. 3.7 First Simple Visualisations of Potential Phenomena

As a first step to evaluate the Phenomena Internet of Things concept, the current implementation still needs to incorporate the key element of collective identification of valuable patterns and the presentation thereof to the user for feedback, or for use in user-generated application eventually. For this purpose, we plan to build a data broker agent, also cooperating with a Bell Labs research department specialising in the data mining aspects and related relevant techniques. In line with Dinoff et al. (2007) and Kim et al. (2009), we plan to model the subject's (be it a human, a software agent or a smart object) learnt habits and intentions, for the first order identification of candidate Phenomena. We expect to get stable and consistent results from this for each subject, in line with the MIT *Reality Mining* project's[51] finding that people have predictable *Eigenbehaviours*.

The versatility and intuitivity of the visual representation is another aspect we plan enhancing, in order to meet the Ingredient 2 discussed before. We aim to provide the users with an easy control tool for monitoring the own personal and environmental data, especially from sensors and devices as specified by the user him/herself, as we believe this to provide a much more motivating experience, which can naturally entail user appreciation feedback. In this way, we envision to start exploring this most important new dimension of the Phenomena Internet of Things concept.

3.6 Conclusion

Motivated by the socio-cultural practice of *'Do-it-Yourself'* (DiY) as apparent in society, we presented a first analysis towards the enablement of mass creativity in the Internet of Things in this chapter, leveraging the DiY movement. With the new possibilities emerging with a *Web of Things* approach, DiY and the Internet of

[51] http://reality.media.mit.edu

Thing promise to become a powerful combination that has the potential to boost to mass scale.

From a typology of how people can potentially create and customise applications, services and objects on top of the Internet of Things, we elaborated three concepts forming a basis for new creation paradigms in smart spaces, potentially leading to new DiY-enabling functions in Internet of Things service creation environments: the *Call-Out Internet of Things*, the *Smart Composables Internet of Things*, and the *Phenomena Internet of Things*.

Considering the applicable state-of-the-art for implementing parts of these concepts and with first experimental grounding for them, the exploration process around these enabling concepts is ongoing, and several challenges clearly remain. Most notably, while the close involvement of the user in any Internet of Things service deployment and even real user participation in the creation process as analysed in this chapter may be key in tackling the expected *privacy issues*, these issues can be expected to grow to be the biggest challenge in the ever smarter world sensing and automating everything around us. On a more technical level, the underlying architectures also will need to be able to handle the massive sharing of personal or public sensor data, as users will assume performance and ubiquity as a condition for value. Evolution beyond the postulated enabling concepts discussed can as well be expected in the future, giving rise to yet more challenges to come at a more conceptual user acceptance level.

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