Single Value Devices

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Abstract. We live in a world of continuous information overflow, but the quality of information and communication is suffering. Single value devices contribute to information and communication quality by focussing on one explicit, relevant piece of information. The information is decoupled from a computer and represented in an object, integrated into daily life.
The contribution of this paper is on different levels: Firstly, we identify single value devices as a class, and, secondly, illustrate it through examples in a survey. Thirdly, we collect characterizations of single value devices into a taxonomy. The taxonomy also provides a collection of design choices that allow one to more easily find new combinations or alternatives, and that facilitate the design of new, meaningful, effective and working objects. Finally, when we want to step from experimental examples to commercializable *products*, a number of issues become relevant that are identified and discussed in the remainder of this paper.

1 Introduction

After the quantity explosion of information and communication, the desire for quality arises, as also expressed by the slow media movement [19]. *Single value devices* are objects that filter one item out of the constant cloud of information, and display it in isolation on a physical object, making this information much more accessible and prominent and integrating it in our daily lives. These key properties give single value devices the potential to increase the quality of information.

A single value can carry a huge amount of information. The single bit of information that a friend is online on ICQ creates an awareness of the other person, an emotion of sharing presence and activity, and may suggest an action, which is to contact the friend. Embodying the representation in a dedicated (everyday, or especially designed) object has additional advantages. Firstly, it brings more immediacy to the information, compared with opening a laptop, connecting to the internet and searching for the information. Secondly, dedicated objects allow for an almost unlimited variety of designs to represent the information and interact with the user, such as sound, touch, light, movement, whatever can be invented using actuators and sensors, and what people find easy and pleasant to perceive. As we will discuss later, it also gives more possibilities to design for *emotion*. Finally, dedicated objects, more than traditional screen-based devices, allow the technology and the information representation to move into the

background or periphery. The information comes only into focus when needed, and the user is not overburdened with information (cf. *ubiquitous computing* and *calm technology* [29, 8, 30, 27]).

Most existing single value devices come from conceptual experiments and from art and exist only as prototypes. In order to get to mature *products* and to design meaningful, effective and working objects, an understanding of the design choices and their consequences is necessary, which is the core contribution of this paper. Our fundamental question is: *How to design meaningful and effective single value devices?* We will, first, approach this question by investigating the possible characteristics of single value devices. To this end, we present a survey of existing single value devices in Section 2; subsequently, we suggest a taxonomy for single value devices in Section 3. When taking the step from the proof-of-concept or artistic-exploration nature of most existing single value devices to commercially feasible products, a number of design issues becomes relevant, which are discussed in Section 4.

2 Survey of Single Value Devices

In this section we present a chronological survey of single value displays, in order to unfold the space of possible applications and approaches. The objects presented here are often prototypes and results from art projects.

– *Feather*, *Scent* and *Shaker* [23] are pairs of objects shared by two people. In "Feather" and "Scent", one partner has a picture frame, and shows (s)he thinks of the other by shaking the frame. This message of connectedness is communicated to the partner at home in a manner reflecting the transience of thought: through a feather in a cylinder that is lifted by a little fan, or by vaporising essential oil in an aluminium bowl using a heating element. "Shaker" is meant for less intimate friends, and consists of a pair of handsized devices that, when shaken, cause a vibration of the other object.

– The *Dangling String* [30] is an installation for an office environment. It consists of one and a half meter of plastic spaghetti hanging from the ceiling, mounted to a small electric motor. The motor is triggered by the activity on an Ethernet cable. A very busy network causes a madly whirling string with a characteristic noise; a quiet network causes only a small twitch every few seconds. Placed in an unused corner of a hallway, the long string is visible and audible from many offices without being obtrusive.

– The level of web activity is displayed in [18] using ripples in a water tank. A solenoid-driven float triggered by "bits" of web activity creates ripples on the surface of the water; these are reflected on the ceiling using a strong light.

– Also for a working environment is the light installation of [15]. Posters of research projects on the corridor walls are illuminated by spotlights. The light intensity of each spot is determined by the number of hits on the corresponding project webpage over a period of time.

– The *Peek-A-Boo Surrogate*, as one of many examples in [16], is also for a working environment. It consists of a little figure that turns its face to the wall if the

person to which it is connected is not present in her or his office, and turns it front to the room, if the person is available.
– Using touch or temperature sensors, a *White Stone* [26] can detect when one partner takes it in her or his hand, which causes a coupled remote White Stone to produce a sound. A message can be sent back by triggering an internal heating device in the other White Stone.
– *Soft Air Communication* [26] refers to a pair of inflatable chairs that can sense weight and movements. At the corresponding chair these signals are then displayed by light and sound.
– The *Frame* [26] indicates presence or absence of family members. A photo in the Frame rises when the respective person is at home, or is dimmed otherwise. A receptor on a key ring or in a wallet captures the presence of the person.
– The *Kiss Communicator* [7] includes two devices, wireless connected by internet. The sender can blow on her device, which is displayed as a colour sequence on the other device.
– Also designed for partners is *LumiTouch* [9], is a pair of picture frames that are connected to a computer and may contain the photo of the partner. The frames allow for two modes of interaction: in one mode movement is detected which makes the other frame glowing. In the other mode a frame can be squeezed giving a different light effect on the other frame.
– The *Internet Tea Kettle* [2] tells adult children whether parents make tea, i.e. use the tea kettle, which is an inherent element of normal daily activity in the Japanese culture, and indicating that the parents are acting well.
– The *Ambient Orb* [13] is a light ball indicating stock market activity. It can be configured via a company website to display other information. It is a commercial product. Connection is through a radio data network.
– The *Data Fountain* [5] can display stock market information by the height of a water fountain. In the example given, the different heights of three vertical water jets reflect the relative exchange rates of the Yen, Euro, and Dollar.
– The *Fishtank* [25] is designed for motivating people to move more. Employees in an office wear a pedometer, to measure their movement. A fish representing them, displayed on a public screen, grows with their amount of movement.
– *Nabaztag* [3] is a networked robot rabbit with speech, movable ears, and colored LEDs. It has been used as a single value device in applications for communication with a spouse, display of aggregated weather information, and others.
– The *Flower Lamp* [4] opens up to bloom depending on the energy consumption at home: the less energy is consumed the more the flower opens.
– The *Hug Shirt* [21] allows to send a hug via SMS to a mobile phone of the person wearing the hug shirt, and via blue tooth the hug is transmitted to the shirt. Sensors in a hug shirt can capture heart beat, skin temperature and strength of a hug, actuators can physically reproduce these information.
– *Blossom* [22] is a very personal object for a woman reflecting her connectedness to her family roots in cyprus. The blossom is made of stamps that were sent from Cyprus to England at the same time as her family emigrated. It opens when a predetermined amount of rain is detected by a sensor on the family land

in Cyprus. The blossom opens only once to reflect the uniqueness of events in contrast to continuous availability of services.
– *Journeys between ourselves* [22] is a pair of necklaces made for a mother and adult daughter. When one touches her necklace the other's necklace starts trembling softly. The necklaces are very personal objects made for specific persons, where the design refers exclusively to shared memories of mother and daughter.
– The *Smart Umbrella* [28] gives a voice alert if its owner leaves the house while rain is predicted. It combines internet information about the weather (weather.com) with local information, the state of the door.
– The *Babbage Cabbage* [14] uses a red cabbage as display. The acidity level of the feeding water can be modified, changing the colour of the cabbage between violet, purple and green. The cabbage has been used as single value display, with the colour of the cabbage representing information such as health of family members, or the quality of global climate and environment.
– A playful competition device is *ikWin: google battle* [20], consisting of two platforms that can be extended to a couple of meters height. Two people can compete by getting on a platform each, and then giving their name as input. The number of google hits will move the platform up, and the one with more google hits will end up in a higher position.
– *Pairs* [10] is also meant for partners. Two paired objects tremble with increasing intensity when they come closer to each other, and stop if they are put together. Much attention is put on the objects themselves, made from wood, such that it is a pleasure to touch and put them together. Additionally, much effort was put in giving them an individual look and personal history. Technology used includes arduino and wireless internet connection.
– *Scottie* [6] is designed for communication between children in a hospital and their relatives. Each participant has a doll, sending messages is done by shaking the doll or knocking on it, messages received are transformed into vibration and colors. Technology used includes arduino, Bluetooth, and mobile phone.
– Tactile communication between remote parents and their children is supported by the *Huggy Pajama* [24]. It consists of a doll equipped with pressure sensors, to be hugged by a parent, and a haptic jacket, where, by air pressure, the sensation of a hug can be reproduced.
– The *Internet Enabled Furby* [12] is an example of an instrumented toy, which functions as room observer (light sensor) and primitive communication device (ears). It has an ethernet connection and is controlled by an arduino.
– The *CoConatch* [1] is designed as physical warning device for twitter. It can alert a user with sound, movement and light about new messages. The device is connected to a PC using a USB connection. The PC runs a tiny server application to connect the device with Twitter trough internet.

3 Taxonomy of Single Value Devices

The single value devices discussed in the survey above are often highly individual projects, stemming as much from an artistic idea as from technological

developments. Many examples concern connection to your loved ones, ranging from simple presence awareness devices (The Frame [26], The Internet Tea Kettle [2]), to active communication devices (e.g., Journeys between ourselves [22], The Huggy Pajama [24]). Other examples focus on displaying practical information about one's environment, such as The Smart Umbrella [28], and the Babbage Cabbage visualizing environmental issues [14]. Communication technologies range from internet to GSM text messages; some devices are realized as mass-producable objects whereas others are highly individual, one-time objects.

In the following we provide a taxonomy of single value devices. It also describes the design space: for each of the characteristics a design decision has to be taken. In this sense it can serve as a stimulation to reflect on choices made, to explore new combinations, to find white areas in the space of possible designs, and invent new characteristics for meaningful, surprising and playful applications.

1. What are the characteristics of the information displayed?

1.1 Information Direction and Communicative Intent. The flow of information may be between two humans (social information), or human and machine [8]. When an explicit **Communicative Intent** is involved, the connection will always be between humans, and may be unidirectional or bidirectional. Examples are Scottie [6] and the necklaces [22]. In contrast, **Status Information** is unidirectional, and may involve human-machine as well as human-human connections (note that the elderly relatives using the Internet Tea Kettle do not make tea *in order to* communicate this fact to their family members). Other examples are the Data Fountain [5] and Smart Umbrella [28].

1.2 Information Distance represents, for social information, the social distance between the information source and the receiver. It can be described as shells spanning from self to family to society and world [14].

1.3 Information Privacy. The information represented by the single device may be **Public**, e.g., taken from the internet, or **Private** (everything that has (or should have) only personal use). Most human-human connections fall in the latter category. The Smart Umbrella [28] combines both: the information that someone is leaving the house is private, the weather information is public.

1.4 Information Decoupling. Single value devices typically involve one or more aspects of decoupling. **Physical decoupling:** The displayed quantity is not necessary one single physical measurable phenomenon such as temperature, but can also be an aggregate value. For example, the "state of the global environment" displayed by the Babbage Cabbage is a complex aggregate of many information sources. **Geographic decoupling:** network communications allow us to completely decouple the display and the measured data geographically. Blossoms [22] are an good example: the blossom (in England) opens depending on rain quantity on Cyprus. **Temporal decoupling:** the values displayed need not be strictly related to real-time (as in 'here and now'). The project poster spot lights [15] display historical data. Other devices might target, e.g., awareness of changes in bodily health over time, or engender historical awareness by showing the climate at a certain location, ten years in the past.

1.5. Information Source. Communication devices typically obtain their information from **Sensors** in the paired object (e.g., LumiTouch [9], the White Stones [26], and the Kiss Communicator [7]). **Databases and statistics** as available on the internet are another information source. Examples are the Data Fountain [5] displaying currency exchange values, or the Nabaztag [3] indicating the weather by light patterns. As said before, the single values that are displayed need not correspond to a single value that is measured. **Aggregators** can combine information in various ways, ranging from very straightforward to highly complicated information fusion using intelligent learning algorithms.

2. What is the intented impact of displaying the information?

In the first place all devices create **awareness**: your partner thinks of you; your parents make tea (and therefore apparently are active [2]); or the device makes you aware of the CO_2 emission 10 years ago, compared to today. The consequence of awareness is an action or an emotion [11]. **Action.** Some information suggests an action, such as to water the dry plant, going to the coffee room when others are there, make a break, read your tweets, phone your parents. Measuring and displaying personal health status can motivate people to live healthier, as with the Fishtank [25]. **Emotion.** Other information mostly aims to trigger emotions. This often concerns relations between people – as with the various partner devices – but another emotion might be, e.g., *feeling rich or important*, through a personal stock market indicator, or the number of tweets received.

3. What physical object is used for the single value device?

3.1 Is the information displayed through a dedicated object? Most examples use dedicated objects, already existing or created for this purpose. A few, however, use walls and surfaces [18] or dedicated screens [25] for display.
3.2 What is de modality used for displaying the information? Any modality can be used (and: has been used) to represent the information in a single value device: light intensity [15] or pattern [18, 3], sound [26], smell [23], motion [30], Bubbles in a tube [17], trembling [10, 22], etc.
3.3 How *personal* is the object? Some of most evocative examples of single value devices are completely **Individual** objects. For example, the necklaces and Blossom [22] are pieces of art made for individual persons, by exploring what is meaningful to these persons and their relationships and transferring that into a very personal object. **Configurable** objects allow one, to some extent, to personalize a mass produced object object. For the Nabaztag differently patterned ears could be chosen, and there was a great variety of costumes for Nabaztags. A few single value devices are based on **mass produced** consumer electronics gadgets, and their physical appearance is hardly configurable.

4. What hardware technology is used?

Single value devices use a wide range hardware technologies. **Actuators.** In our examples, (LED) lamps are used [9, 18], dimmers [15], speakers [3], in-

flatable components for haptic sensations [24, 21], motors [30], vibraton motors [10, 22, 3, 16], heaters [23, 26], also using bimetall [22], and pumps [5, 17]. **Sensors** in the examples measure quantities such as location (GPS), displacement (accelerometers, distance sensors), presence of objects (RFID), sound intensity, light intensity, temperature, humidity, pressure (touch, air pressure, height), or time (DCF, GPS). **Information transport** is done through PCs, Arduinos or other microcontrollers, USB, WLAN, phones, wires, and web servers.

5. What is required for using the device in daily life?

When aiming at mature products, a number of pragmatic questions regarding actual use of the devices in daily life become important, too. **Setup and configuration.** How much technological expertise is required for setup and configuration (introduction to a network, coupling to a paired device, etc.)? Does the device require regular configuration updates? **Charging.** Does the device need batteries? Frequently having to recharge the device diminishes it's property of being a background service. **Services.** Which basic services, such as wireles internet or mobile phones, are used? Are there associated costs such as renewal of prepaid phone cards? Does the availability of the service depend on the availability of a company server?

4 Design Issues

Underlying single value devices is a fundamental tension. On the one hand, their most important characteristics center on being highly personal and context dependent objects. On the other hand, commercially feasible production requires very different design decisions, like uniformisation.

4.1 Single value devices are objects with associated emotions

Single value devices often represent information with personal meaning, and the object displaying the information should allow for emotional connotation. Consequently, there is the choice of either designing a new, dedicated object as carrier for this information, or taking an existing object with the emotional connotation already associated to it.

Attaching meaning to an object is an action of a person [11], it is not an inherent property of an object. Different people can attach different meanings to the same object. How to design an object that stimulates users to attach emotional meaning to it? In our examples we find two extreme approaches. The necklaces in [22] are designed personally for two people, taking their shared memories into account: e.g., elements from illustrations of fairy tales read together. The other extreme is to design a very neutral object and give space for projecting meaning to it. The white stones [26] and the CoConatch [1] have a tenuous design allowing for different connotations.

Another choice is to equip *existing* personal objects – that already carry emotional meaning for a user – with technology, as done with the tangible bits

[18]. A very invasive strategy is followed with the internet enabled Furby [12]: after treatment it cannot be used anymore as a normal Furby. A more restrained approach is that of the Lumitouch photo frame [9] carrying a personal photo. To generalize the approach of non-invasive technology added to existing objects, we suggest to develop light-giving pedestals or small display cases in which one can put highly valued personal objects.

4.2 Customizability

Configurability is the answer of consumer electronics to individual needs when, at the same time, concentrating on cheap mass production. For single value devices it is crucial to keep them simple, Not all target groups will want to, or be able to, configure their device.

However, one key property of single value devices is that they are highly context dependent. Some people may want to see status information about global warming; others might prefer a single value device to display the severity of traffic jams, each user has his or her own loved ones whom (s)he wants to connect to. Functionalities may not be relevant in every context, e.g., the pollen status is mainly relevant in spring. From this point of view, single value devices need to be extensively configurable.

Aspects that need to be simple for each user are initialization, such as introducing to the local network, or pairing with another device.

Altogether, it is obvious that a range of devices is necessary to satisfy different needs. Configurability is a feature that should be included carefully balanced with simplicity. In order to meet requirements from producability we suggest a generic platform as discussed in the following section.

4.3 Building blocks for single value devices

In principle, it is not difficult to build prototypes of single value devices in all flavours. Still, from a practical point of view, the design of a prototype requires effort, knowledge and technological experience. For end users and their evaluation, prototypes easily suffer from lack of every-day convenience. Aspects like small size, simple chargability or connection to the internet, are typically not the first requirements in prototype development – but for usability these aspects are very important.

We suggest the development of a platform that can serve as a standard basic setup for single value devices. It should be easy to equip with a range of sensors and actuators, easily accessible for the software part, easily connect to internet, and aspects as charging sorted out. The advantage of such a platform would be: for the researching developer, who can efficiently develop prototypes, using a kind of universal building block, for the product developer, who can build on a flexible standard platform, for the end user, as basic usability of such a product is present, for the producer, who can produce such a platform in high numbers and use it for different products.

We have made a start with developing a standard basic setup for single value devices used in a *coffee rendez-vous application*, as an example application.

4.4 Service dependence

Permanence of service availability is a topic that is often overlooked in the development of prototype single value devices, but which is very important when they are to become commercial products. We make things that depend for their whole life cycle on payed connectivity services such as telephony networks, radio datanetwork or internet. Additionally, many devices need a webserver for registration, configuration, storage of data, and dedicated applications. Quality of service, regular updates, and sufficient variation in the available applications is a crucial factor in the commercial success of a product.

5 Conclusion

Single value devices have a potential that is not yet realized. They can integrate into daily life in an unobstrusive and aesthetic way. The variety of applications is huge, from motivating to live healthier to reminding of everyday duties, from telepresence to simple playful communicators. But still, very few commercial products exist. Most of the examples available are prototypes exploring conceptual design choices. Aiming at commercial products a more integral view on single value devices is necessary, to which the work presented contributes.

We investigated the design choices by, first, exploring existing examples in a survey, and, in a second step, distilling the characteristics in a taxonomy of single value devices. The taxonomy in itself is already useful to identify unexplored areas in the design space. Furthermore, we contribute a critical discussion about how to design objects with emotional connotation, which is certainly underlying in many publications and prototype developments on single value devices. Further discussions address customizability, and the service concept that inherently gets introduced with single value devices. Our future efforts will aim at a more mature version of the hardware platform, and a variety of projects where we prove our platform and explore the possibilities of applications.

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