Bringing Context to the Foreground: Designing for Creative Engagement in a Novel Still Camera Application

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ABSTRACT
Sensor-based interaction has enabled a variety of new creative practices. With ubiquitous computing, designing for creative user experience with sensor-based devices benefits from new opportunities as well as new challenges. We propose a design approach where surrounding context information is brought to the foreground to become a resource for interaction, available at hand and in real time to the users. We illustrate this approach with our project context photography as a design case. Context photography consists of taking still pictures that capture not only incoming light but also some of the additional context surrounding the scene, with real-time context information visually affecting the pictures as they are taken. Based on the design and use of our context camera prototypes, this paper brings insight into implications of our approach to the design of sensor-based ubiquitous computing systems for creative purposes.

Categories and Subject Descriptors
H.5.2. Information Systems – Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design, Human Factors.

Keywords
Digital photography, context photography, sensors, context, creativity, engagement, everyday use, real time interaction.

1. INTRODUCTION
An important break-through in the development of interactive systems happened when sensor-based information started to enable users to engage with them through other modes of interaction than e.g. screens and keyboards (e.g. through voice or gestures). This opened up for richer and more engaging interactions and for a range of creative applications and practices based on physical engagement, such as performance-oriented live electronic music making [4]. With the advent of ubiquitous and mobile technologies, sensors are now even embedded into everyday objects and portable electronic devices. Computing devices can for instance expand and become 'bigger' by taking in aspects of the surrounding environment as extra resources, while everyday physical artefacts can gain a digital presence. This new type of merging of the digital and physical world can potentially open up for a wide set of new possibilities for creative computer uses, expending to everyday settings. The everyday context in which people live could become for them a resource available at hand for creative uses.

Ubiquitous computing typically relies on the augmented object or device rather than the user, to obtain increased awareness of the world [24]. For instance, context information is often kept and processed in the background of the user's activity and awareness, in order to off-load tasks and cognitive load from them and support the activity in a non-obtrusive way. However, in applications meant for creative purposes (e.g. photography or music making), dealing with information in such a way would promote a passive relation between the user and the everyday world that the sensors would otherwise open to: although the system and the environment would interact, the user would not be directly allowed to get actively involved. This would potentially impair their sense of creative engagement in the use of the system. In order to enable users to attend to what the system senses, i.e. the everyday world, and consciously engage in the use of this data, we suggest a change in approach to context information, This consists in providing users with foreground and real-time access to context information, as opposed to keeping this information in the background.

We have worked on a project called *context photography* where we designed and prototyped a *context camera* as well as studied its use. The context camera is a novel digital still camera that uses context information to *visually* affect images in real time ([16], [19]). When taking a picture, the user captures not only incoming light but also some of the additional context surrounding the scene. Users can for example take still pictures of a noisy setting and get certain visual qualities depending on the sound level at the moment of capture. In developing this camera, environmental context information was brought to the foreground in a way that made it a real-time resource for interaction. This allowed users to have an active role in the interplay between the device and environmental factors.

Some aspects of the design process of the context camera were described in [16] and [19], and its use in a long-term user study was detailed in [15]. In this paper, we aim to specifically show how bringing context information to the foreground in a ubiquitous computing system for creative purpose – in the case of context photography, by making it visible in the picture when taking it – and thereby making it accessible for users to interact with in real time, can open up for new engaging and creative user experiences. We begin with a presentation of the concept of context photography and of its related work. We then continue with a high-level account of the prototyping process of the context camera, followed by a presentation of our design rationale. Finally, we conclude with a discussion about the

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implications of bringing context information to the foreground in real time that could be valuable to designers of sensor-based ubiquitous computing systems for creative purposes.

2. BACKGROUND

The digital still camera has now become a truly pervasive device, either as a standalone artefact or integrated into mobile phones. With resolution, automation and ease of use having greatly improved, current digital cameras have also become very sophisticated photographic tools, worthy of their analogue counterparts. The new digital nature of still cameras has allowed new means of sharing and editing images, and changed our perception of what a photograph is and how much it represents reality [22]. However, in terms of actually taking a picture, digital cameras have so far been very similar to analogue ones and have not really exploited the new possibilities that digital technology could bring to picture-taking. As Martin and al. argue: "[d]igital photography means more than being able to download, manipulate and distribute images: it could allow image capture to play many, and more poetic, roles in our lives" [23].

Sensor-based ubiquitous technology has the potential to bring such a new dimension to digital cameras, as sensors have previously allowed for a wide range of creative interactive applications [4], and as their use in ubiquitous computing devices brings with them novel relations to the everyday world. Data such as e.g. environmental information, location, gestures, the presence of objects or users, biometric data, can be used. How to process, interpret and map this information is however far from trivial, and there is an on-going discussion about ways of doing this in order to design for meaningful user experiences (e.g. [7], [8], [24], [25]).

In the context photography project, we were initially interested in exploring what would happen if one added sensors to a digital camera and sensed the context of the scene to add something to the picture: to get a "bigger picture". How could such information be used in an interesting, sensible and aesthetic way? Could environmental information be used in an image similarly to how light and time are used in traditional cameras? How could this become a new enjoyable photographic experience to users?

2.1 The Notion of Context

The notion of *context* is widely discussed in the fields of human-computer interaction, ubiquitous computing and social science, among others. While Dey defines context as "any information that can be used to characterize the situation for an entity (place, person or object)" [6], Dourish argues that context also derives from social dynamics and that this aspect of context is often neglected in the design of context-aware systems [8]. In ubiquitous computing, context information is most often either used in real time by the systems, or stored for later use, and is mostly utilized to support a task or practice by providing relevant information or services depending on the user's goals. Accordingly, a context-aware system is defined as one that "adapts according to its location of use, the collection of nearby people and objects, as well as changes to those objects over time" [29], or as one that "uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task." [6].

In photography, the notion of context is also multifaceted, with both visual and technical perspectives defining it. In traditional photography, the notion of context usually refers to the various socio-cultural factors that affect what meaning we make from or give a certain image. According to Sturken and Cartwright [31], "[t]he capacity of images to affect us viewers and consumers is dependent on the larger cultural meanings they invoke and the social, political, and cultural contexts in which they are viewed." From a technical perspective, context is usually referred to as metadata, i.e. contextual or camera related information, such as shutter speed or ISO number, saved along the photograph when it is taken.

A number of research prototypes make use of metadata and sensor-based information about context to support aspects of taking pictures. For example, Holleis et al. [13] have built a context-aware camera that gathers context information (e.g. the photographer's movements) to support people in taking "better" pictures. Users are immediately provided with information about how they took a picture, in order to suggesting adjustments and other tips to help them become better at it. Information from sensors has also been used to tag pictures and facilitate browsing through image or video databases. For instance, *LAFCam* [20] automatically detects laughter to index video recording with points of interest such as scene involving fun. *StartleCam* [12] uses a skin conductivity sensor to measure excitement, which triggers a video camera to start recording potentially interesting content without a direct intervention of the photographer.

Such approaches to using context information were mainly meant to support more efficient or easier use of the camera, at the same time as the contextual tagging of images potentially added new dimensions and meaning to them. For instance in [23], another approach was explored where photographs were tagged with audio files in provocative ways. In context photography, context information in relation to the picture-taking moment had instead the potential to become a creative resource. With resulting context images, traditional notions of context would still apply, since the way they would be viewed and interpreted would still partly depend on social, political and cultural settings – as for regular photographs. However, both the picture-taking moment and the resulting images would gain a new contextual aspect, different from what had previously been referred to as context in relation to photographs.

2.2 Augmenting the Digital Camera

In what way could augmenting digital photography with context information then be done in order to provide interesting new means of taking pictures?

In ubiquitous computing, a predominant approach to augmenting devices with context information – the pro-active approach – has been to map this input to various system behaviours (actions, responses, etc) performed automatically. This processing of contextual information is often not made accessible nor even perceivable to users and is handled in the background of the system. An example of pro-active ubiquitous computing is a meeting room that turns off the lights when it does not detect movement and concludes that no one is there at that time [5]. This also exemplifies the distinction between implicit and explicit interaction that characterises interactions with sensors (e.g. [25], [30]). Explicit interaction happens when the coupling between sensor and activity is easily understood by the user because of instant feedback on his/her actions, e.g. when pressing a button. The term implicit interaction applies to more passive interactions, such as when a user triggers a sensor, e.g. by being close to it but without necessarily needing to know what it takes to activate the application or when it happens. In the meeting room example, this means simply being present and active. Usually, sensors are specifically assigned to enable either explicit or implicit interaction, depending on the modalities of the application [25]. Applying such a pro-active

approach to augmenting a digital camera would be to make it context-aware, e.g. make it sense the context of use of the camera in order to tag images for later retrieval (as in [20]), automatically trigger the picture-taking when reaching certain conditions [12]. However, if not careful, a pro-active approach could be contra-productive, in a way similar to cameras that do not allow to take for example blurry pictures (e.g. by freezing when objects are too close) – even if the user actually wants to!

Another approach to the design of ubiquitous computing systems was highlighted by Rogers in [24], who promotes an alternative agenda for ubiquitous computing that would focus on designing technologies for *engaging* user experiences. As opposed to pro-active computing where devices make decisions for, and sometimes in spite of the user, this approach meant designing for pro-active people – not systems – who would become more actively engaged in what they do. Playful and learning practices, scientific practices, and persuasive practices are some examples of application areas where ubiquitous computing technologies can be designed with, in order to create more engaging and meaningful experiences for users. Such systems would help users change habits and take control over situations, or help them in a learning process through interaction with and exploration of the physical-digital spaces. In the same vein, several researchers have highlighted new design challenges emerging when interaction becomes embedded in everyday life as it does with ubiquitous computing systems (e.g. [2], [3]). New values and demands on the design of systems and interfaces become relevant, such as the need to be aesthetically appealing, inspiring or provocative, rather than just be fit to solve a particular task. Dimensions such as uncertainty, ambiguity and lack of control could be valuable resources for design and open for interesting user experiences (e.g. [2], [9], [25]). Context photography takes a similar design approach when augmenting the digital camera, making use of context information for an everyday life practice (i.e. taking pictures) and with a non-task oriented approach. However, instead of focusing on engagement in learning or gaming practices, we focused on designing for engagement in creative practices.

Some ubiquitous computing technologies have already been appropriated for creative purposes by the general public. For instance, GPS (Global Positioning System) drawing is a novel practice where users create large-scale virtual drawings (such as e.g. an elephant in the scale of an area of Brighton) by logging GPS data while physically moving through urban space [11]. Hinting at the potential of this type of technology for creative purposes, such appropriations show how the physical and digital spaces and conditions can be used, produced and combined in a creative way.

In context photography, we aimed to explore an alternative way of taking digital pictures that could be exciting and interesting to users for playful and explorative everyday use. Our approach thus leaned towards an aesthetic use of context information that differed from making a context-aware camera: the user would actively influence the aesthetics of the pictures with environmental context information from sensors affecting the pictures in real time, as they would be taken. Instead of acting as a support to the act of taking a picture, context information would become an inherent part of the process and thus a potential creative resource for the camera user.

2.3 Bringing Context to the Foreground

As this paper aims to establish, we believe that one promising way to design for engagement in creative ubiquitous systems is to bring context information to the foreground and thus turn it into a resource available at hand for users to interact with in real time in their use of the system. This approach can be related to the idea of seamfulness [1], where network "seams" are made visible to pervasive gaming participants as a real-time resource in playing the game. A number of systems for everyday life engagement or personal expression have had a similar approach and used sensor-based information as parameter or, in other words, used features of the real world available at hand as resources. *I/O Brush* is a tangible digital paintbrush that allows children to pick up textures, colours, and movements from the real world and use them as a digital "ink" when drawing on a board [26]. This system makes use of the user's familiar environment by turning it into a colour palette; letting the children explore their immediate surroundings and use them as a resource available at hand for their drawings. Also dealing with context and thus more closely related than I/O Brush, Sonic City is one early example of an engaging system that lets users interact with urban context information for creative purposes [10]. Wearing sensors on their body, users can create a real-time personal soundscape of electronic music by walking through and interacting with urban environments, thereby using the city as a musical interface.

Our approach of foregrounding context information in real time brings up a number of design opportunities as well as challenges in terms of mapping the digital and physical worlds. Besides the issues of enabling active user engagement, digital media needs to match an already existing everyday world in a meaningful way; a world with inherently dynamic, heterogeneous qualities that create sensor input that is as rich as it is unpredictable. Designing for use in everyday life settings, with its constraints and existing web of meaning, rather than for particular occasions such as e.g. exhibitions, further adds new challenges. Below, we detail the process of designing the context camera in order to highlight these issues and show how foregrounding context information enabled active user engagement and creative behaviours.

3. DESIGNING THE CONTEXT CAMERA

The concept of context photography and the context camera were developed in an iterative user-centred design process, each iteration resulting in the implementation of a prototype or in its refinement. All prototypes were based on the principle of mapping sensor data to computer graphic effects that were applied directly to the image in real time. However, each prototype had different purposes in exploring the concept of context photography and varying levels of complexity. Below we will describe our prototyping process and our design rationale, as well as discuss the implications they led to on the subject of engaging uses of context information.

3.1 Prototyping Process

As stated earlier, our initial idea for the context camera was simply to add environmental sensors to a digital camera and sense the context of the scene to add something to the picture; i.e. to get a "bigger picture". In order to ground the design of the context camera, we involved users in several of the prototyping iterations. As we were interested in breaking free from preconceived ideas about means of taking pictures, we turned to alternative photographic practices for inspiration. We were not necessarily looking for a group of end-users, but rather for a source of inspiration that could help us open up to unconventional forms of photography and generate interesting ideas ([16], [17], [18], [19]) We became familiar with the alternative practice of *Lomography* [21]. This practice gathers a

Figure 1. Iterative prototyping: concept prototype (a); interaction prototype (b); camera phone prototype (c).

worldwide community of photographers who deliberately use a certain kind of defective analogue cameras to take pictures with surprising visual results. Lomographers have an explorative and humorous approach to photography that embraces mistakes and serendipity. We considered such qualities of picture-taking to be interesting for us to get acquainted with in the design of the context camera. Therefore, we involved a group of three local 'lomographers' in a *concept design workshop* at an early stage of the design process. We aimed to capture the underlying qualities of the lomographer's practice [17] without ending up designing a "lomo-camera" per se. The workshop consisted of a discussion about photography in general, their practice in particular, and the concept of context photography, as well as small participatory design exercises [16]. From this workshop emerged the idea of letting context information manifest itself by visually and aesthetically affecting pictures; as opposed to being provided as raw data or as a complementary file (e.g. as a sound file to inform about the audio context of a scene). This led to the development of a first simple and limited prototype where visual effects affected images in real time based on simulated sensor input [16]. This *concept prototype* was implemented on a PDA, using a camera jacket (Fig. 1.a). The PDA's screen was used as the viewfinder, and simulated sensor values could be manually manipulated to affect the pictures in real time, changing hue, saturation or value (Fig. 2.b). With a similar size-factor and shooting mechanism as a regular digital camera, the device emphasised aspects of real-time image processing by giving a feeling of how sensor values could manifest themselves in photographs. It served as a probe within the research team and helped us generate design ideas about mapping and visual effects that we further developed in the design process.

In order to design for physical and real time user experience, we then developed a working *interaction prototype* with real sensors and real-time visual effects that could test simplified yet realistic use, as well as explore issues related to real context input [19]. This prototype was a platform for iterative prototyping and was thus implemented on a Tablet PC for easy re-programming. It had regular digital camera functions such as pressing a button to take a picture, audio feedback when pressing it, and displaying images on the viewfinder (Fig. 1.b). The computer screen acted as a viewfinder and a USB-webcam served as a lens. Context information consisted of sound and movement information. Movement was retrieved through the webcam as a vectorial field, and sound level was obtained from a microphone attached to the Tablet PC. In order to obtain interesting aesthetic visuals with the computer graphic effects, we collaborated with an interactive media artist who had previously worked on mapping visual effects to movements in his interactive installations. He implemented the software platform and helped us developing four different sets of effects, each visualising context in different ways.

With this interaction prototype, we were able to involve the same lomographers as well as other amateur photographers in hands-on testings in situ [19]. We conducted two *user workshops* with a total of five users, each workshop consisting of an open session where the participants freely used and tested the prototype in everyday settings, followed by a semi-structured group discussion about the use. Feedback about the user experience (e.g. sense of control, personal expression, aesthetics, etc) from the user workshops led to design implications and to a re-design phase of the interaction prototype, together with the interactive media artist. This highly iterative phase involved continuous testing within the research team, which took place in various environments in order to fine-tune the settings and functionalities of the prototype according to users feedback.

The resulting application was then ported to standard camera phones (Fig. 1.c) in order to facilitate testing with real users in everyday situations. The overall functionality of this prototype did not change between the interaction prototype and the camera phone one, apart from the fact that visual effects had to be optimised and adapted to fit the conditions and size of a smaller device. The final context camera prototype was thus an application running on camera phones (currently Nokia 6600 and 6630) that used sound and movement as context information. It utilized the device's own hardware (microphone and lens) as sensors: the microphone was used to sense sound level and spectral distribution, and the image stream from the camera itself was used to identify instances of movements as a vector field in the picture. The application was programmed in C++ using the graphics library GapiDraw [27] – a multi-platform computer graphics library available for various handheld devices – as well as optimised algorithms from the Tablet PC software. The interface allowed the user to capture images, see the resulting photographs, save them, browse through the pictures and delete them in the same way as with a regular camera phone. The user could choose among the four graphical effects and calibrate the sensitivity of the sound and motion sensing. Each picture was named after time and date of capture for logging purposes, and was saved together with a copy of the image without effects. This final camera phone prototype was tested in a longer exploratory study with seven users [15], who had been told how the camera worked technically but had not been instructed what kind of pictures to take with it or how, following Sengers and Gaver's advice to leave the system open to interpretation [28]. The study, which took place in the users' everyday life in various locations around the world and lasted for a period of 6 weeks, revealed how participants used and perceived the context camera as a new photographic device.

3.2 Design Rationale

In designing a camera that would sense and foreground context in real time, our design criteria were for the camera to become a creative tool for amateur photographers that would be fun, engaging, suitable for everyday use and with which users would be able to take aesthetically pleasing photographs. Below, we

describe our design rationale in fulfilling these criteria, and the user experience resulting from it.

3.2.1 Sensing Context: Sound and Movement

What aspects of context would be sensed was an important issue in enabling engaging interaction. While experimenting with the concept prototype, we felt that taking a context picture should be allowed just as much to be a long process, as to be one that could happen in a split second. We also felt that one should be able to take a wide range of different pictures within a limited amount of time if so desired, in order for the experience to be exciting. Therefore, we found that dynamic aspects of context such as sound would be more suitable than e.g. temperature that would change very slowly. Sound and movement, two dynamic contextual factors, were chosen as input based on these considerations and on the fact that they were relatively easy to begin implementing with. They had the advantage of not requiring any sophisticated sensing, as they could easily be retrieved from off-the-shelf devices (external microphone and webcam) with the Tablet PC, and did not require extra hardware on the camera phone.

In both the user workshops and the longer-term user study, the users tried to obtain effects by using the context camera as an 'action camera'; actively seeking action moments and dynamic situations to take pictures in, or creating or "faking" sound and movement to achieve interesting effects (Fig. 2.c-f). This could involve e.g. chasing loud vehicles in motion, asking other people to generate movement or sound by waving or screaming, or doing it oneself. As one user study stated, "*[y]ou move yourself or the camera more. Spin it etc. Just to try to get a fun effect*". Regular photography sometimes involves taking pictures of dynamic things, but looking for action was truly an essential part of the context camera experience. As one study participant commented: "*Context photo made me after a while search for movements and noise to succeed […] And this rendered a new and interesting experience and results.*" Our choice of foregrounding dynamic aspects of the context thus strongly affected what users took pictures of and how, adding spontaneity to the user experience. As one user put it: "*I would probably never have spontaneously taken a picture for example of a car passing by if it hadn't been for the effects that the application gives*."

Another challenge for the context sensing part of the camera was to try matching what the camera senses to how the user experiences a situation, as the context was now brought to the foreground. At first, the context camera did not allow for calibrating sensor sensibility. Feedback obtained during the user workshops were that users sometimes felt that the camera reacted too little or too much – for example sensing hand movements when they felt they were holding the camera still – or that the camera could not discriminate between sound levels coming from different sources. Moreover, as the intensity of a contextual factor is highly subjective, the perception of a same factor can vary between different situations and places. The user might perceive a sound to be louder than what the camera does, or feel that temperature during a hot summer day is the prominent aspect of context, even though this will not be registered by the camera at all as it senses other parameters. We found that users might wish to exaggerate or tone done certain factors as a creative act. Therefore, we added a calibrating function to the camera during the re-design of the interaction prototype. This made it possible for users to calibrate movement and sound sensibility individually, and thus to decide for themselves how much movement and sound should influence the pictures. In this way, user were able to adapt the sensibility

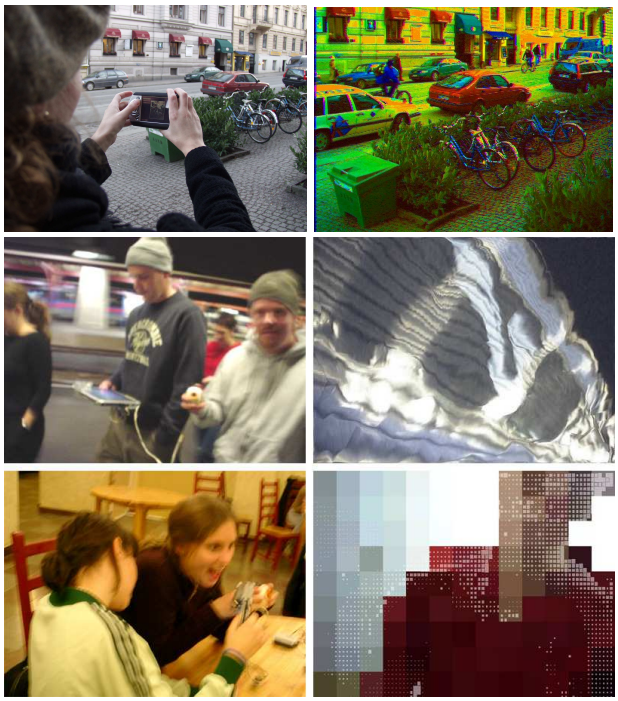

Figure 2: Project team member using the concept prototype (a, b). Workshop participants (c, e) taking pictures of a departing train (d), and screaming to pixelise a portrait (f).

of the camera to their own perception of certain settings, as well as modulate the sensor input (e.g. exaggerate or tone down) at wish, which we hoped would give them more control and the possibility to better express themselves. This calibration did prove to be an important factor in providing user control during the longer user study. One study participant for example switched off the movement sensing to focus on sound.

However, the participants still did not feel entirely in control of the output, because of the dynamic nature of the input. Sounds and/or movements could also sometimes be out of reach of the sensors, for example being too fast, too sporadic or too low. Dealing with the dynamic nature of sound and movement thus also implied not being entirely in control of the outcome, something that turned out to be both a challenging and fun experience: "*much of the fun with context photography is that you feel you are not entirely in control over how the picture will turn out. The situation will determine this…*" This added a dimension of serendipity to the use of the camera.

Context photographs were thus shaped by both users and the context, with users being, on one hand, physically engaged in making creative and spontaneous use of their surroundings and other means at hand, and on the other hand, regulating how much the context would influence the picture while leaving room for chance and creative accidents.

3.2.2 Mapping Context to Still Images

When designing a mapping strategy that linked *dynamic* context information – with transient characteristics in time – to visuals qualities in a still image – static in time, our choice of input had brought with it interesting challenges and opportunities.

Throughout the process of deciding how sensor data and visual effects would be mapped to each other, we aimed for this connection to be transparent (e.g. easy to learn), as well as complex enough to be interesting for everyday life use under long periods of time. This was motivated by feedback from

workshop participants as well as Hunt et al.'s [14] research about the relation between mapping complexity and pleasing music playing experiences with alternative music controllers. In the concept prototype, we used correlated effects (hue, saturation and value) in order to loosely mimic the way that parameters (speed, aperture and focus) depend on each other in analogue cameras. When starting to map real sensor data to visual effects in a more systematic way, we first opted for a one-to-one mapping strategy for all four sets of effects, where sound and movement would each influence their own effects in a orthogonal way (i.e. their impact on the picture would be independent of one another). While this strategy was relatively straightforward to grasp, we were concerned with the fact that some participants of the user workshops had complained that aesthetically pleasing pictures were too easy to take. They valued effort in creative processes and thought that this easiness was somewhat equivalent to cheating. In Hunt et al.'s research about mapping strategies in alternative music controllers, results show that simple mappings – although easier to learn because less challenging than complex ones – are less stimulating in the long run than complex ones. Complex mappings are more interesting when making music because they provide a more stimulating challenge and require more effort to master. Transposing this principle to photography, we thus experimented with designing more complex mappings in order to increase the level of user effort in taking satisfying pictures. Instead of dealing with effects separately, the users would have to juggle with interrelated factors, for example with sound influencing one parameter of a movement-related effect on the images. We replaced half of the original one-to-one orthogonal mappings we had first implemented in the Tablet PC camera with many-to-many correlated mappings, in order to require more effort from the users to manage the camera and hopefully stimulate new creative uses. This mapping strategy was kept in the final camera phone prototype and seemed to have had beneficial effects on the use of the camera, as none of the user study participant had similar comments about this issue at that point. The fact that users had various different strategies of using the camera (switching off effects, screaming, etc) also seemed to point toward this direction [15].

Another question regarding mapping was that of choosing what would be considered as default values for the sensor data, as well as what corresponding default settings the effects would have (f. ex. is default quiet or noisy?). Moreover, what would be seen as minimum or maximum values and how easily should these limits be reached? What would these limits mean for the perception of a picture? Effects could for example reach a maximum when sensor input would be at its lowest and fade away when things would happen in the scenery; or they could have negative values such as inverted colours when for example sound input would be below a particular ambient level. In any case, we wished to avoid getting too extreme effects when a situation would for example be completely quiet or extremely noisy. All circumstances were to correspond to an image, as opposed to pictures getting for example completely black or white. After testing out various options, we decided that default input values would be that of a silent setting with no movement, and that this would correspond to a normal image without effects. In this way, things would happen in the picture effect-wise, when things would happen in the setting context-wise. In the user study, this contributed to the interesting result that users preferred certain things to photograph compared to others. Subjects that normally would be considered interesting to take a picture of in regular photography were no longer interesting in context photography, unless they involved sound and movement. Quiet situations were much less attractive to photograph since they would not result in any effects: "*It [the picture] does indeed reflect the reality. It was calm and quiet. But it is a boring way to use the application. Therefore [it is] also a bad context photograph.*"

These results highlight the role of the mapping – i.e. the way the foregrounding is framed – in the users' experience, their sense of engagement as well as in the way they apprehend resulting images.

3.2.3 Representing Context with Visual Effects

How should sound look like in a picture? How does one visually convey a sense of activity in a still image? Although we only used simple hue, value and saturation in the concept prototype, the visual effects in the interaction and final prototype were thoroughly crafted. During the several iterations of the interaction prototype, we took inspiration from contemporary visual aesthetics that are popular in youth culture (for example Lego-like pixels), tested out suggestions from users and worked in close collaboration with the interactive media artist. As we focused on studying underlying characteristics of effects rather than their individual looks, we prototyped and refined four different sets of effects to be able to compare between them. Sound and movement effects were combined based on how well they would aesthetically fit together as well as how well we felt they would represent various contexts together. We also wished for the effects to be ambiguous enough (e.g. aesthetic as opposed to directly "readable" as in the field of information visualisation) to be open for users to interpret them subjectively, since "ambiguous situations require people to participate in making meaning" [9]. Figure 3 shows images obtained with these sets of effects in the first version of the interaction prototype: colour shadows with specific shades following movements (a), extreme zooming on things in movement (b), small white dots following movement and pixel size increasing with sound level (c), movement creating waves(d), and colours evolving towards grey and sound level(a, b, d – visible in b)

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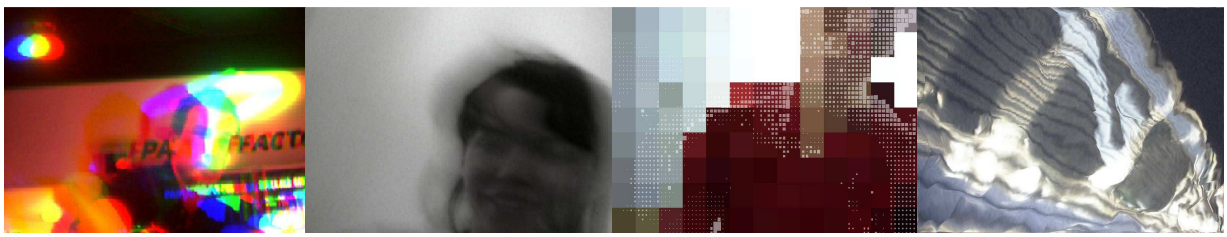

Figure 3. First iteration of the visual effects in the interaction prototype: colour shadows (a); zoom (b); pixel (c); wave (d).

In the user workshops, participants expressed concerns about many pictures turning out to look somewhat the same regardless of who took them and where. This made the effects appear too pre-designed rather than taken by someone specific and emerging from and depending on the environment – which was after all the main goal of context photography. This happened for instance in the colour shadow mode where the shadows had pre-determined shades. In order to support uniqueness for personal expression as well as give a stronger sense of connection between the pictures and their corresponding context, we experimented with changing the effects in such a way that their visual qualities would reflect particular contexts more specifically, for example by picking up colours from the scene to use dynamically. However, actually picking up colours from the scene proved to be unsuccessful, as the resulting images tended to all look rather brownish and dull. Instead, we opted for letting the colour shadows that followed movement in one of the effects change colour according to the sound spectrum (Fig. 4.a-d), which gave more subtle and versatile effects than in the first version of the effects. Combined with increased user control through calibration and complex mapping, the idea behind making the resulting pictures look more individual was also meant to increase the user's sense of personal expression.

Another important feedback from the user workshops was that the effects needed to have visual aesthetics specific to context photography – a "real-time" aesthetics – that could not be confused with regular photography or post-edited images. Users considered the effects to be part of the identity of the images as context photographs, besides connecting effects to situations more strongly. Grey scales, which resulted in images too reminiscent of traditional black-and-white photography, were thus for example replaced in the wave mode by increasing pixel sizes (Figure 4.j), which was considered more unique and interesting by participants.

Some concerns were shown by the users about some effects being too extreme, and about not being able to see the motive anymore. The zoom effect for example was thus modified into having an always visible layer with the untouched image in the background, and having the zoomed image overlaid on top of it as a transparent layer, in order to preserve motive and its framing (Fig. 4.e-h).

Finally, the wave effect following movement, which used an algorithm based on fluid mechanics and tended to oscillate, could cause a picture to be left without visible effect if the oscillation was passing zero at the time the camera was triggered. This caused frustration to the users as situations with a lot of movement would sometimes not cause any wave. We therefore made the algorithm correspond to a thicker fluid that would progressively go back to normal without oscillating (Fig. 4.m-p).

The need for these changes showed the difficulty of subjectively interpreting context and of designing effects that related enough to place, time and the dynamics of a scenery in the picture-taking, while still not being over-designed.

The final effects and corresponding mappings became the following:

1. *Colour shadows*: Traces of coloured shadows follow movement; the colour of the shadows is affected by the frequency of the surrounding sounds (Fig. 4.a-d – correlated mapping)
2. *Zoom*: The part of the picture with most movement is zoomed in, and rendered as a transparent layer on top of the rest of the image; the amount of transparency is determined by surrounding sound level (Fig. 4.e-h – correlated mapping)
3. *Pixel*: Small white dots follow movement as a decaying trace; the size of the pixels in the picture is proportional to the surrounding sound level (Fig. 4.i-l– orthogonal mapping)
4. *Wave*: Movement creates waves in the image, making it look like a dense liquid. As in 3, the size of the pixels in the picture is proportional to the surrounding sound level (Fig. 4.m-p – orthogonal mapping)

In the user study, we also found that context photography brought a new type of aesthetics. Preferred aesthetics of context pictures were highly subjective and very much a matter of personal taste. Two separate visual effects could obviously have different appeal for different people in representing the same context. However, for all users, images needed to reach a balance in the amount of visual effects in order to posses an aesthetic value. As explained earlier, users expected to obtain visual effects in the pictures. Another aspect was that images were opened to ambiguous interpretation. One user for example felt as though he could "see" the wind blowing in a picture he had taken of a harbour.

3.2.4 Real-Time Image Manipulation

In context photography, photographs are affected by context in real time, which provides direct feedback and which results in new types of connection between the user, the subject of the photograph and the time and place of the picture-taking. It enables users to act spontaneously and on the spot, which directly affects the picture. For the participants of the user study, the real-time aspect of image manipulation in context photography "*immediately show[ed] an alternative visual perception of the experienced environment*". Experiencing how the visual qualities of images directly result from the situation also created a strong connection to the original place and time in which the pictures were taken: "*In some way it feels more real. I did not manipulate this picture afterwards, this is how it WAS…*" This constitutes a fundamental difference from regular post-image processing: "*Here and now is important. Otherwise the whole thing loses its point*". Therefore, real time did not only provide a "directness" in context photography, but also proved to be important for the users in terms of getting a feeling of uniqueness and "here and now." The real time dimension in foregrounding context therefore had an important role in the experience of context photography.

Finally, one concern for the user workshop participants was centred on the lack of sense of *still* photography (as opposed to e.g. video or other kinds of moving images). At first, the effects were continuously visible on the viewfinder prior to taking the picture. This made the camera sometimes feel more like a motion camera when observing effects change in real time on the viewfinder, due to the dynamic nature of the input. When watching the movement effects in action before taking a picture, one user workshop participant sometimes forgot to take pictures, as she became more interested in seeing the effects change continuously than in the final still images. On the contrary, other users did not enjoy seeing the effects constantly, and had rather seen them once the picture was captured, as they considered it would make the use more exciting, in a way similar to opening a bag of freshly developed analogue pictures for the first time. Therefore, we opted for only displaying the effects of the image once actually taking the picture as opposed to beforehand, and only displaying the image without effects

Figure 4: Context pictures with the final visual effects: colour shadows (a-d); zoom (e-h); pixel (i-l); wave (m-p).

before that. This proved to add a dimension of effort and creative engagement in the user study, as users had to experiment more in order to obtain pleasing pictures. It also added a dimension of surprise and excitement, reminiscent of seeing how traditional pictures turn out after development. Small modifications of the camera could thus potentially affect whether it was still perceived as a still photography camera or not.

4. DISCUSSION

The design of the context camera as well as its use during the user workshops and the long-term user study brought insight into what it implies to use context information as a real-time resource available at hand for a creative practice. Foregrounding context information made the experience of using the context camera engaging for the users, and spawned new types of creative behaviours. Below, we will highlight and discuss issues that we believe are valuable in general for the design of sensor-based systems making use of context information for creative purposes.

4.1 Blending Explicit & Implicit Interactions

> *Bringing context to the foreground made users engage into a combination of explicit and implicit interaction. This can open up for engagement by both allowing for personal expression and leaving room for the unexpected.*

Results showed that context photography implied a mixture of implicit and explicit interaction. On one hand, users interact implicitly with the camera simply by being in an environment with ambient sound and movement, and letting the context contribute to affecting the images. As the environment is dynamic, users cannot always control its impact, but can modulate it with calibration. On the other hand, users can interact explicitly with the camera by actively creating input, seeking a moving/noisy source of information or modulating sensor input, and instantly see the result of this in the pictures. Instead of the designer deciding beforehand for the sensor data to have either an implicit or explicit function (as in e.g. [25]), in the context camera the same sensors are *both* implicitly and explicitly used and it is the users who manage this themselves in their use, although not necessarily reflecting about it as they go about. With context brought to the foreground, users can thus give it several interchangeable roles. Pictures can be taken *of* the context as a subject, *with* the context as a passive contributor and/or *by* the context as an active contributor. The explicit interaction made it possible for users to explore, learn and develop skills in context photography, a crucial aspect in creative systems since an important part of the satisfaction comes from becoming better at it. Although the implicit dimension of the interaction might have been frustrating to some users since it implied less control, to others the serendipity could add fun and spontaneity to the use of the camera. However, one could argue that the nature of the user interaction in context photography partly depended on our choice of sensors. In context photography, we have so far only used sound and movement as input, two parameters that are highly dynamic, possible for users to influence, and that are constantly present in our everyday life (e.g. traffic, people,

music, etc.) Other types of sensor data such as pollution or electromagnetic fields that are more static or even invisible to the user in the physical world (thus more difficult to act on), would probably allow for less explicit interaction. In any case, we believe that this interesting mixture has helped opening up for novel engaging user experiences, by both allowing for personal expression and leaving room for the unexpected. It made the camera "bigger", by taking in aspects of the world. As they come in, these aspects influenced the picture-taking practice, the resulting photographs, as well as the relation between the photographer and what was being photographed.

4.2 Balancing the Need for Thorough Design with An Openness to User Appropriation

> *Mappings and representations need to be thoroughly designed, but should still be open for the user to use, interpret and appropriate.*

The context camera needed a careful mapping strategy and thoroughly designed visual effects, but was still open for different interpretations according to what the user preferred. In I/O Brush [26], raw sensor data was directly used without prior representation, which made the system very open for creative use. In context photography however, we needed to interpret the sensor data and translate them into another medium, i.e. images, which added a dimension of subjectivity [19]. As such representation and use of context information were novel and unconventional, there were no preconceptions about what the results should become, resulting in the designer's subjectivity being emphasised and in a risk of over-designing the camera. We believe that avoiding to over-design mappings and representations was important, and that one should let them remain ambiguous enough for users to interpret them and create their own use and meaning for them. As Gaver et al. [9] point out: "ambiguous situations require people to participate in making meaning". Sengers and Gaver [28] further argue that remaining open to interpretation is "particularly important for systems intended for use in domains more open than the workplace, where peoples' relative freedom to choose their own experiences with and through technology may be undermined by technologies that convey strong narratives about their preferred uses." At the same time, this partially addresses the issue of personal expression: users should be able to appropriate the camera and create in such a way that they feel reflects their own personal expression. Ambiguous mappings and representations not only give rise to images open to interpretation, but also can leave more room for personal expression.

4.3 Modifying the Activity of Taking Pictures

> *Ways of foregrounding context information can potentially modify the nature of the media.*

Context photography brings context to the foreground as a real-time resource available at hand for creative use – as opposed to using this information as a pro-active support or to manipulating images later in time. Thereby, it has brought new dimensions to the activity of taking still pictures, and new parameters to manipulate beyond speed, focus and aperture. This led to a different approach to taking pictures focusing on action and spontaneity, a new relation to time and place captured in images, etc. However, as when the sense of still photography had been lost when the effects were constantly visible before even taking the picture, making such modifications to a creative tool can make it loose the things that make it what it is. Preserving the nature of the media can be a design issue to take into consideration.

5. CONCLUSIONS

We have presented our design and study of the context camera in order to illustrate our suggested approach to the design of ubiquitous computing systems for creative purposes. This design case showed how bringing context information to the foreground in real time – here by making it visible in the picture when taking it – and making it into a real time resource available to users at hand, could open for new engaging and creative user experiences. This presented new design opportunities and challenges, by involving both the user and their surroundings in a mixture of implicit and explicit user interaction resulting in both spontaneity and serendipity; by requiring for designers to balance the need for careful crafting with an openness for user appropriation and ambiguous interpretation; and overall by providing new means for personal expression situated in the immediate "here and now".

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