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Workshop at INTERACT 2013 – 14th IFIP TC13 Conference on Human-Computer Interaction, Cape Town, South Africa, September 2013

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Peripheral Interaction: Embedding HCI in Everyday Life

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Abstract. The comparison of actions in the physical world with actions on interactive devices reveals a remarkable difference. In daily life we easily perform several tasks in parallel, e.g. when drinking coffee while reading this text, drinking may be in the background or *periphery* of the attention. Contrarily, we almost always have to focus our attention on each digital device we interact with. Considering the growing number of devices competing for our attention, novel interaction techniques have to be explored to offer *Peripheral Interaction* with digital devices. We believe that this approach supports interactive technology to be better embedded in everyday routines. This workshop aims at bringing together researchers and practitioners from different disciplines, to share their experiences with human-computer interaction (HCI) for the everyday routine and to shape a shared understanding of *Peripheral Interaction*.
Keywords: peripheral interaction; human attention; trained routines; calm technology; ambient information; interaction design.

1 Introduction

Computing technology has become increasingly present in everyday life. This creates opportunities as well as challenges for interaction design. One of these challenges is the seamless integration of technology in our everyday routines. A large body of related work, in areas such as calm technology [9] and ambient displays [4], addresses this by aiming at moving away from presenting information in a salient way, toward presenting it subtly, blended into the environment. Though these areas target background perception of information, we now see an upcoming interest in background interaction with computing technology [1-5, 8], which is the focus of this workshop.

This vision, which we call *Peripheral Interaction,* is based on the observation that in everyday life, many actions occur outside the focus of the attention [2]. For example, we can easily tie our shoelaces while having a conversation or drink from a cup while reading a book. These actions are seamlessly embedded in everyday routines.

Similar to everyday actions, Peripheral Interactions are interactions with technology, which occur outside the focus of the attention and fluently blend into everyday life.

This workshop aims to bring together a community of researchers and practitioners with various backgrounds (e.g. computer science, interaction design, interactive arts, psychology, product design, social science), to discuss and create a common ground for future research on Peripheral Interaction. Besides people working on Peripheral Interaction or directly related topics, we especially invite those interested in better fitting interactive technologies in everyday life and challenge them to think of their work as a Peripheral Interaction. The workshop addresses the following questions:

What is Peripheral Interaction? The term Peripheral Interaction is used in various ways, for example to describe interfaces located on the side of the user's visual field [3]; to describe brief actions performed in parallel to other activities [5, 8]; or to encompass both background perception and interaction [1]. Also, several other terms are known that describe related interaction styles, such as eyes-free interaction [7] and implicit interaction [9]. The first goal of this workshop is to create a common understanding and comprehensive definition of Peripheral Interaction.

How to put Peripheral Interactions into practice? To gain a common understanding of Peripheral Interaction, not only high-level definitions but also practical, interaction level knowledge is required. In this workshop, we will discuss how (potential) Peripheral Interactions can be put into practice through presentations of participants. Based on this we will explore the common attributes of Peripheral Interaction. This is relevant to (1) recognize Peripheral Interaction, (2) support Peripheral Interaction researchers, evaluators and designers and (3) find opportunities to evaluate and improve existing interactions from the perspective of Peripheral Interaction.

How to evaluate Peripheral Interaction? A major challenge of Peripheral Interaction is evaluating it. Most evaluation methods known for HCI, seem unsuitable to evaluate if an interactive system blends into everyday life. To assess this main goal of Peripheral Interaction, one needs to deploy it in an everyday context for a period of time [4]. Since this approach is demanding and time-consuming, it would be interesting to explore alternatives. Using the participants' experiences as a starting point, we will discuss evaluation strategies that are suitable for Peripheral Interaction.

2 Workshop Goals

This workshop has the following four main goals. (1) To create and bring together a *community* of artists, practitioners, engineers, designers and researchers with various backgrounds who are directly or indirectly working on Peripheral Interaction. (2) To share and discuss *definitions* in order to create a common understanding of Peripheral Interaction. (3) To share and discuss (potential) examples of Peripheral Interaction, in order to identify their common attributes. (4) To share and discuss *evaluation strategies* suitable for Peripheral Interaction.

3 Structure of the One-Day Workshop

Before the Workshop. Potential participants submit a position paper (up to six pages), addressing the authors' work and its (direct or indirect) relation to Peripheral Interaction. Participants may bring demonstrators or videos to show their work, but this is by no means a requirement.

During the Workshop. The workshop will kick-off with a presentation of each participant, in the form of a talk, video or demo (chosen by the participant). Next, participants will informally get to know each other in a "speed-date" by sharing views on Peripheral Interaction, followed by a keynote of Albrecht Schmidt, entitled "Creating Seamless transitions between Central and Peripheral User Interfaces". In the afternoon, interaction examples will be enacted and discussed in small groups to establish common grounds for Peripheral Interaction. After a break, one group will do a creative activity on design for Peripheral Interaction and another group will explore evaluation strategies. The workshop will wrap-up by summarizing the results and thereby aims to lay foundations for a structured exploration of this new interaction paradigm.

After the Workshop. Accepted submissions will be included in workshop proceedings, published as technical report as well as on the workshop's webpage. This webpage (www.peripheralinteraction.com) will also host a blog and a forum for a continuation of the community-building on Peripheral Interaction after the workshop.

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A Context Server to Allow Peripheral Interaction

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Abstract. This paper presents a research to create a mobile context server application that provides other applications with complex context information. The main objective is to avoid disrupting or overwhelming users with explicit requests for data that can be obtained otherwise by the interpretation of combined sensor data. It is mainly aimed at mobile devices used by people with disabilities to allow them to interact with local services supplied by means of ubiquitous computing.
Keywords: Context awareness, people with disabilities, accessible ubiquitous computing.

1 Introduction

There is an increasing variety of services provided by local machines, such as ATMs, information kiosks, vending machines, etc. These services are frequently inaccessible for people with disabilities because they are equipped with rigid user interfaces. Nevertheless, the application of Ubiquitous Computing techniques allows access to intelligent machines through wireless networks by means of mobile devices. Smartphones can provide an excellent way to interact with ubiquitous services that would otherwise be inaccessible. People with disabilities can benefit from this type of interaction if they are provided with accessible mobile devices that are well adapted to their characteristics and needs.

The INREDIS[1] project created a ubiquitous computing environment to allow people with disabilities to interact with locally provided services. In this project our laboratory developed EGOKI [1], an automatic interface generator that is able to create adapted and accessible user interfaces that are downloaded to the user device when she or he wants to access a ubiquitous service.

Nevertheless, when users are immersed in an "intelligent environment" they can become overwhelmed by the quantity of explicit interactions that they have to manage through their mobile device. For this reason we are working on ways to enhance a mobile device's context awareness to ease the interaction with the aforementioned services.

[1] http://www.inredis.es/default.aspx

2 Related Work

User attention is an interesting concern for interaction with a ubiquitous system. The work of Weiser & Brown (1997) distinguishes two levels of attention: central and peripheral. The central attention focuses on the main task that is being addressed by the user, while the peripheral attention is related to "what we are attuned to without attending to explicitly" [2]. Additionally, in multitasking environments the user’s attention can be negatively affected by interruptions. Leiva et al. (2012) reported that interruptions while interacting with an application can delay by up to four times the completion of a task in a mobile environment [3]. Thus, two conclusions can be drawn: it is desirable to ensure that users can pay attention to applications around them without feeling overwhelmed; and it should be attempted to maximize the focus of the user on a single central task, reducing shifting between tasks.

Two different ways to get the attention of the user are described in the following lines. On the one hand, it is possible to merge background interaction with peripherical attention. The work of Bakker et al. (2012) [4] presents an interactive system called FireFlies to explore the way in which primary teachers are able to manage secondary tasks in the periphery of their attention. The intention is to study “how interaction with technology can fluently blend into people’s everyday routines, similar to the way in which interactions with the physical world are a part of routines”. Using this approach, tasks that would require direct attention or a cognitive effort disappear from the central attention of the users. On the other hand, a slightly different approach is to consider the implicit human-computer interaction. Schmidt (2000) [5] defined this as “An action performed by the user that is not primarily aimed to interact with a computerized system but which such a system understands as input.”. This work studies different sources to add implicit information, with the most relevant to this work being “sensing context using sensors”. Schmidt described sensor-based perception as a way to recognize the implicit context and illustrates some examples that can help to manage interruptions and limit the need for input when users are interacting with computers. Therefore, the implicit context can be useful to free a user’s attention from a specific task.

Concerning the supporting technology, two approaches stand out in the literature: The first frees the user's attention by using wearable devices. Saponas (2010) defines the always-available interaction, describing methods to interact with a mobile device without using it explicitly [6]. Likewise, a user can receive notifications from applications using smartwatches as a second screen at a glance[2]. The second proposal enhances the context-awareness of ubiquitous applications using smartphones. Smartphones and the sensors within them are useful to characterize activities and recognize context information. Reddy et al. (2010) were able to distinguish between the movements of the smartphone user (stationary, walking, running, biking, and travelling in a motor vehicle outside) using the GPS receiver and the accelerometer [7]. In a similar way, the work of Wiese et al. (2013) recognizes whether a mobile is in a bag, in a pocket or in the hand [8].

[2] Sony Smartwatch (http://www.sony.com/SmartWatch) or Pebble (http://getpebble.com/)

3 A Context Server for Peripheral Interaction

In our case, peripheral interaction includes all the implicit activities that are conducted to interact with an application. Our objective is therefore to collect, by means of sensors, any type of information that helps the device to manage the interaction, thus minimizing the need for explicit user participation. This is called context information and we gather it by means of sensors that are located in the mobile device, either worn by the user or deployed in the environment.

Usually, each mobile application has to collect and process data from the sensors available in the device in order to adapt the interaction to the context. This is frequently done in real time and competing with other applications, which limits the possibilities to extract complex results.

Our approach focuses on a context server application that collects data from the sensors, combines this, and extracts complex information that can be directly used by the other applications.

3.1 From Sensing to Perception

In order to determine what information is provided in each case, we created a sensor taxonomy that classifies the different types of sensors that are currently found in mobile devices or worn by users. This taxonomy allows us to work with “abstract sensors” independently of their specific datasets.

To extract combined information we developed an ontology of sensors, including rules that specify the type of information that can be obtained from the combination of different sets of sensors.

3.2 From Perception to Interaction

Our context server can contribute to peripheral interaction by providing the applications with valuable information that would otherwise be explicitly requested from the user.

The context provider can assist developers to make use of the context in a simpler way. For instance, the context server allows applications to select the most appropriate modality to interact with a user with communication restrictions, due to disability or to a situational impairment. For instance, if the microphone detects that the local level of noise is too high the application can avoid voice commands and prioritize text or images; or, if the inertial sensors detect that the user is walking, driving or riding a bicycle, touch input can be switched to voice input.

In addition, some applications for people with disabilities use the server to perform their tasks without disturbing the user. In the following lines four examples of freeing users’ attention using our context server application approach are described.

3.2.1 Affective Interaction

Affective computing focuses on detecting and reacting to emotions by using computers. Emotional information can be useful to understand and detect the context of the user when interacting with an application. The work of Haag et al. (2004) presents an example of inferring a user's mood and emotions using physiological signals [9] obtained via sensor devices that measure heart rate variation, perspiration, respiration rate, skin temperature, etc.

The context server application can detect and manage the data from the wearable sensor devices and infer information to feed applications with information about the mood of the user. This is valuable for the peripheral interaction. For instance, it is possible to avoid stressful situations that occur when a user has to attend to too many tasks simultaneously. In a similar way automatic rearranging of the tasks can be performed to distinguish the enjoyable ones from the annoying ones.

3.2.2 Smart Wheelchair

Smart wheelchairs are robotic platforms to assist people with mobility restrictions to navigate the physical environment. Smart wheelchairs are equipped with sensors (sonar, laser range finder, bump sensors, etc.) in order to perceive elements that can affect the navigation. Thereby, diverse modes of operation are developed to assist the user including: collision avoidance, wall following or close approach to objects [10].

Controlling a smart wheelchair with a joystick can become a stressful task. Situations such as approaching a narrow space or going through a door may require a high level of concentration. In such a scenario, the context server application would discover and integrate the wheelchair sensors. The data collected is helpful to infer when the user is facing a stressful situation. The context application server provides this information to the wheelchair, which can trigger automatic guidance procedures.

3.2.3 Smart Traffic Lights

There are smart traffic lights that assist people with special needs to cross the street safely. For instance, current Audible Pedestrian Signals[3] (APS) attached to traffic lights help people with vision impairments to know when they can walk across a pedestrian crossing. In addition, works such as UCARE [11] present prototypes for scenarios where impaired users can negotiate via their mobile devices the period required to cross the road. If the user has to handle the device when approaching a pedestrian crossing, his/her attention is disrupted. However, this task is moved to the periphery by using the context application server. The speed and position of the user are gathered using accelerometers and GPS and sent to the traffic lights to activate the APS. Moreover, the mobile device can negotiate, in the background, the time required to cross without the explicit participation of the user.

[3] APS are also called accessible pedestrian signals: http://www.apsguide.org/index.cfm

3.2.4 Peripheral Interaction with EGOKI

As mentioned in the introduction, EGOKI is a UI generator for ubiquitous services. The user's abilities, device characteristics and service functionalities are taken into account to create an accessible UI. For each function of the service or application, EGOKI selects the appropriate input/output elements to ensure a suitable interaction [1].

The context server application empowers EGOKI to allow peripheral interaction for some applications. Firstly, it helps to detect appropriate input and output methods; for instance, by allowing the use of gestures when a wearable device with accelerators or an electromyogram is detected. Secondly, it helps to choose the communication modality in an accurate way. For instance, when blind users are in a noisy environment, avoiding speech and audible channels would be an issue. Instead of that, the volume of the user device should be adapted to the noise level. Finally, when the context application server provides accurate information about the user, the UI generation process avoids having to explicitly ask the user for that information. For instance, when an application needs the user location it is provided by the context server and EGOKI excludes that input element from the final UI.

Therefore, some ubiquitous services will not require explicit attention from the user and due to the change of modality would run in the periphery of the user's attention.

4 Discussion and Conclusion

There are a number of issues that require our attention when merging peripheral interaction with the context server application.

To begin with, peripheral interaction can be contradictory with a well established practice of activity-aware systems. As mentioned by Mahmud et al. (2009) [12], activity-aware systems must inform the users to correct failures in activity recognition to avoid mistakes and manage uncertainty. This would increase the number of interactions that a user must perform and would consequently draw his/her attention more than necessary.

In addition, context information depends on the set of sensors detected by the context application server. Users can be affected by the loss of smartness when the availability of sensors changes. This is related to the "masked uneven conditioning" challenge stated by Satyanarayanan (2001) [13].

Moreover, the application domain is a key factor for activity recognition. The accuracy of the activity and emotion recognition techniques "in the field" frequently produces worse results than in the laboratory. In a similar way, the accuracy of the results depends on the person.

Finally, the impact on a user's privacy must be considered, because large quantities of data about the user are collected and logged. These data must be protected to avoid their unauthorized use; for instance, by commercial applications.

The combination of sensor data allows the interpretation of the context at a higher level, providing mobile applications with implicit methods of interaction that augment communication without disrupting the user's attention for routine adjustments.

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Peripheral Interaction in the context of DJing

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Abstract. DJs constantly negotiate between their social and technical roles while performing and often encounter conflicts in their needs to interact with the audience vis-à-vis their tools. In recent times, HCI researchers have focused on tools and systems for DJs to manage interactions with their audience. However, there is a need to design 'calm' systems that help the DJ manage their social interactions better and that has minimal interference with their primary tasks. Interpreting this problem through the lens of Peripheral Interaction holds the promise to suggest appropriate solutions that might lead to a better understanding of the broader fields of crowd computer interaction and designing for spectators.

Keywords: Peripheral Interaction, DJs, Nightclubs

1 Introduction

DJs adopt a wide variety of social and technical roles while performing in nightclubs. As musicians operating in an inherently technology-led domain, their performances involve interacting with tools and their audience [1]. These interactions often occur in busy settings and compete with each other putting a strain on the DJ's attention. DJs could benefit from immediate feedback from the audience while performing, but tend to avoid direct interaction since doing so interferes with their more important tasks such as browsing music libraries, manipulating controls to manage the music stream, etc. Moreover, the context of their work (usually dark settings) makes it difficult for them to easily shift their attention back and forth between their tools and the audience, resulting in scenarios where the audience interaction becomes limited to body gestures and direct observations of the crowd. An interpretation of this problem through the lens of 'Peripheral Interaction' could point to new ways of approaching this design space and consequently contribute to a richer understanding of the broader fields of crowd-computer interaction [2] and designing for spectators [3].

2 Related Work

HCI researchers have shown considerable interest in recent times in understanding the needs and work contexts of DJs and proposed technologies for them to manage their work better. Gates et al. classify some of the early works as nightclub specific interactive technologies in the domains of audience-centered applications, DJ-centered applications, and applications for DJ-audience interaction. These applications took advantage of sensors, mobile devices and communication technologies in the form of playful applications, performative spaces, automation and mixing tools, and systems based on bio-feedback [1]. More recently, Ahmed et al. conducted ethnographic studies around DJs and give a good account of the more recent studies around DJs that proposed multi-modal prototypes (e.g. wireless, mobile, haptic, and multi-touch) as DJ tools [4].

However, we argue that most of these proposals require the DJ to pay direct attention to the tools and hence run the risk of interfering with the intensive primary task of a DJ: playing music.

3 Observations

Our previous work briefly describes some in-situ observations on how the resident DJs we studied negotiate their social interactions while performing [5]. We noted that the DJ's social circles acted as a resource for receiving feedback. It highlights the need to differentiate the different degrees of relationships that a DJ has amongst the audience. We are interested in exploring how technology can help the DJ manage a two-way interaction with the audience in a 'calm' [6] way, without a substantial increase in his or her cognitive load.

As part of this process, the lead author of this work has been engaged in long term ethnographic studies of DJs and, in the spirit of overt 'participant observation', has performed 12 gigs over the last two years in the capacity of both a DJ and a VJ. In one of the recent VJ gigs, an interesting phenomenon was observed; people familiar to the VJ rolled empty plastic bottles to his feet to draw his attention, which they needed to show appreciation of particular moments during the performance. Others in the audience observed and imitated this behavior and it gradually turned into a playful and socially acceptable way of expressing appreciation. Another observation was that while VJs project and control visuals directly based on the music, the DJs often are unable to see the projected visuals because of a need to direct their attention to their primary task. Both these observations point to the need for understanding the periphery of their attention and how some of these social interactions can be supported by designing non-intrusive interfaces.

4 Peripheral Interaction

We are currently working on a few design directions that have resulted into a number of concepts for the nightclub settings. One of the concepts is a tangible interface or an interactive system for the DJs that would be connected to projectors beaming colored blobs downwards onto the crowds on the dance floor. The DJs will be able to interact with sections of the crowd by mainupating these color blob projections. However, one of our primary concerns is to design the interaction paradigms in such a way that they are playful and useful but at the same time have minimal interference with the DJ’s interaction with the music making tools.

The presentation at the workshop will be structured around a series of edited video snippets illustrating performers’ behavior as they seek to engage audience members as a secondary task to their core performance activities.

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On the Relevance of Freehand Gestures for Peripheral Interaction

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Abstract. Interactions in the visual and attentional periphery can help to perform secondary tasks without an attention shift away from the primary task. In this paper, I define freehand gestures as imprecise moments towards any device or object in the periphery of a user. This kind of gesture can be interpreted by the device and understood as an attempt for activation or deactivation. The interaction can be performed eyes-free, which is an advantage compared to controlling haptic elements such as buttons. The paper will provide example use-cases, advantages and constraints of the approach as well as issues I would like to discuss at the workshop with experts on the field of peripheral interaction.

Keywords: peripheral interaction, freehand gestures, eyes-free interaction, workshop

1 Introduction

While working on this paper for a workshop on peripheral interaction, I direct my full attention to the display standing on my desk. On the screen, multiple windows are open at the same time such as a browser, Word and a PDF viewer showing all the related work. As if the task of writing this paper would not be difficult enough, little but necessary interactions with other devices on my desk distract me from my main task. The deadline is approaching, which increases my stress level. The music, which is usually very welcome while I am sitting on my desk, suddenly becomes rather annoying. I reach for the speaker to find the on/off button, which I am not able to find right away. I need to look at the speaker, push the button and get back to work. How was I going to finish the paragraph again? An hour later, the sun just disappeared from the sky, it gets too dark to see the notes I wrote on a piece of paper. I reach to the left to find the light switch for the reading light on my desk. Where did it go? I look to the left to find the switch and reach for it to turn on the light. I turn my head back to the screen. Which sentence was I working on again?

Of course, these are only exemplary but also well known situations. In both cases, it would have been helpful to succeed in my first attempts without having to look at the devices I was going to activate. The attention shifts away from the screen towards other devices on my desk interrupted my concentration and cost me valuable time in a stressful situation.

But, what if both devices, speaker and reading light, would have been able to interpret the movement of my hand towards them and to guess my intention to deactivate or activate them? My imprecise gestures would have been sufficient to fulfill my tasks, there would have been no need to look at the devices to find the one button I was looking for and I would have been able to keep concentrated on my paper.

The purpose of this paper is to point out a characteristic of simple freehand gestures: Hand and arm movements can be performed in a rather vague way compared to the interaction with ordinary haptic control elements such as buttons or switches. We should try to make use of this advantage in the field of eyes-free interaction in order to allow the control of devices in the visual and attentional periphery [5]. In the following paragraphs, I will provide some exemplary use-cases, advantages as well as possible drawbacks and constraints of this approach. Furthermore, I will report on an experiment from the automotive context, were eyes-free interaction is even more critical. Twenty drivers used a simple gesture to deactivate certain functionalities while driving and received positive quantitative and qualitative feedback.

2 Freehand Gestures

I define freehand gestures as movements of the hand and the arm in order to interact with a digital application without the need to touch a device or other physical representation. As sensors such as Microsoft Kinect or LEAP Motion provide a cheap and relatively easy way to track gestures, their importance in the field of Human-Computer-Interaction has increased. In the automotive context, studies involving freehand gestures have shown their ability to decrease visual distraction [2], helping the driver to better focus on traffic. Thus, gestures have a great potential to enable eyes-free interaction [9]. One reason is that movements performed by hands and arms can be monitored via the kinesthetic sense due to the feedback from muscles and joints. Because of this inherent feedback, visual attention or additional artificial feedback is not needed during the interaction itself. Therefore, freehand gestures can be used for research in the area of peripheral interaction [1, 6].

Though, the design of gestural interactions has a strong influence on their applicability for peripheral interaction. A gesture performed in the periphery without an attention shift away from the primary task is only possible if its naturalness can be maintained. E.g. a rather large or arbitrary gesture set works against the advantage of natural interaction [8]. Gestures need to be learned and remembered and thus using the right gesture for a certain action requires additional attention, which is a problem for peripheral interaction. For this reason, required movements should be kept simple.

3 Approach

For the reasons stated in the previous chapter, I would like to stress the importance of a certain property of freehand gestures: Compared to the usage of haptic control elements, where the movements to and the activation of the button needs to be very precise, a gesture can be performed in a rather vague way using imprecise movements. Considering the exemplary use-cases described in the introduction of this paper, a simple gesture can replace the interaction with the on/off button of the speaker to turn off the volume and the actuation of a switch to turn on the reading light (see Fig. 1).

In general, each movement of a hand close to a certain device could be interpreted by this device. In our case, the system can 'see' how a hand reaches towards it and interprets this movement as an attempt to being activated or deactivated.

The tracking of the hand and its movements can be realized by using infrared distance sensors, which are integrated in each device in a reachable distance to the user. By interpreting the values of all active sensors, the system is able to detect the single device a user is reaching for.

Fig. 1: Turning on the light by simply reaching towards the lamp

4 Prototype

Visual distraction of the driver is a critical issue in the automotive context. Controlling e.g. the infotainment system via a touchscreen or a number of haptic controls is already a difficult task itself. To accomplish this task while concentrating on the primary driving task produces an even higher amount of cognitive load. Therefore, my colleagues and I implemented a prototype [7] enabling a simple freehand gesture to control certain functions while driving in city traffic for about 15 minutes.

Twenty drivers were able to use the stop-gesture (approaching a device with the whole hand, see Fig. 2) to turn of the ventilation of the air conditioning (AC), mute the volume of the radio and stop the route guidance of the navigation system. In order to recognize the hand of the driver, we attached two distance sensors, one below and one above, to each of the three devices (see Fig. 2).

To be able to gain realistic insights into this kind of gestural interaction, we chose a between-subjects design, where each driver used haptic controls in one round of driving, the stop-gesture in the other round of driving and had the choice of using either type of interaction in the last round of driving. To avoid order effects, half of the participants started with gestures and the other half with haptic controls.

The quantitative results of an AttrakDiff2 questionnaire, which all participants filled out after each round, show that gestural as well as haptic interaction has a high pragmatic quality. At the same time, gestures have a higher hedonic quality, meaning that the use of the stop gesture did not only fulfill the purpose of deactivating certain functions, but also was considered to be the more attractive type of interaction.

Qualitative results from interviews after all three driving rounds show that 14 out of 20 participants favored the gesture over haptic controls. In the third round, when drivers were allowed to use either type of interaction, they chose the gesture for 91 out of 120 tasks (76%). 16 out of 20 drivers stated that the use of the gesture helped them to better focus on traffic, which is especially relevant for peripheral interaction. One driver stated that "turning off the radio is especially helpful in stressful situation, just like when I am entering a crowded parking garage to find a parking spot, where I usually switch of my radio to be able to concentrate better".

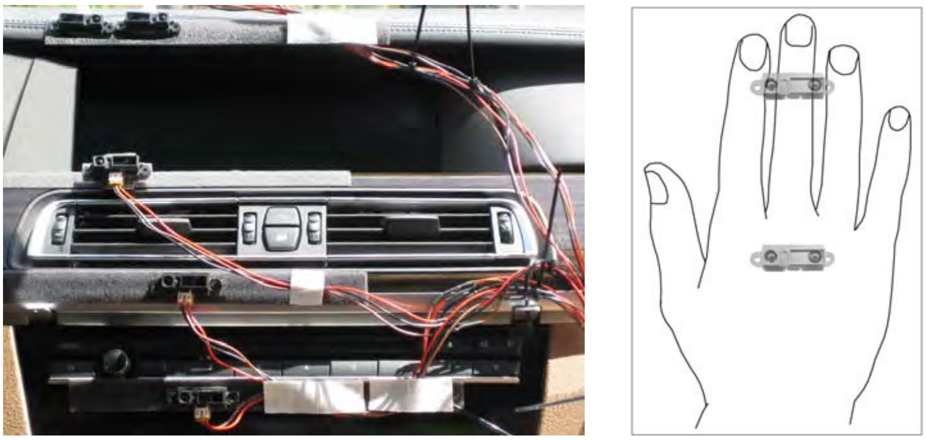

Fig. 2: Distance Sensors on the Dashboard of a car (left) detecting a Stop-Gesture (right) [7]

All in all, the results of the study allow us to draw conclusions, which are interesting for the field of peripheral interaction. The application of a simple stop-gesture, which basically describes the movement of the hand towards a certain device to deactivate its functionality, has proven to be pragmatic and attractive to the drivers in real driving situations. One reason for drivers choosing gestural over haptic interaction was the feeling that it helped them to better focus on traffic while performing a secondary task. Considering the use-cases described in the introduction, this approach can be transferred to the desktop, where secondary tasks like turning on the light while focusing on the computer screen are performed on a regular basis.

5 Outlook

To provide a natural way of peripheral interaction with a system via gestures, it is important to keep the set of possible gestures rather small. The need to think about the correct gesture in a certain use case would hurt the principles of eyes-free and therefore peripheral interaction. On the other hand, a small gesture set limits the number of possible interactions with a certain application. Considering the use-case of interacting with the audio-player [5] of a desktop computer, users will probably ask for more detailed controls. A possible step towards this need is the mapping of the distance of the hand to the speaker: the closer the hand, i.e. the smaller the distance between the hand and the speaker, the quieter the music, and vice versa. How far this additional possibility still meets the requirements for peripheral interaction, needs to be studied in future experiments. The workshop on peripheral interactions offers a great opportunity to discuss the issue of how the number and kind of gestures influence their applicability for eyes-free interaction without shifting attention to this secondary task.

Furthermore, there is a possible conflict between the needed impreciseness of the movements and the segmentation issue of gesture tracking. E.g. if I only move my hand to grab an apple laying next to the lamp on my desk, the light should not be activated. This case of a false positive gesture recognition would result in confusion about the accidental interaction. An attention shift to the lamp and an interruption of the primary task of writing the paper would be inevitable. When designing for peripheral interactions using gestures, the trade-off between the advantages of vague moments and the resulting problems for gesture tracking need to be taken into account.

Another issue, which needs to be considered during the design of peripheral gestural interaction, is the type of feedback given to confirm the success of the performed action. As mentioned above, kinesthetic feedback is directly given by muscles and joints while moving hand and arm. While muting an audio-player or turning on the light without paying visual attention, functional feedback [10] is given by the corresponding device itself: I can hear that no music is being played anymore and I notice that the room is not dark anymore without a shift of my visual attention towards the lamp or its light bulb. With other functionalities, such as disabling notifications from a messenger such as Skype, direct functional feedback is not perceivable. Therefore, when gesturing towards a physical representation of Skype, such as the StaTube [4], the device needs to provide an additional artificial feedback. A possible solution is the changing color of the StaTube, indicating the success of my action in an ambient way.

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Towards Ambient Notifications

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Abstract. In this paper we report on two studies for displaying information in the periphery of the user's attention. One experiment explores the use of ambient light to inform users of upcoming tasks in an office scenario, while the other investigates whether vibro-tactile displays can become peripheral. We show that both modalities have potential for conveying information outside a user's focussed attention.

Key words: Ambient light display, reminder, interruptions, user studies.

Peripheral Interaction: Embedding HCI in Everyday Life http://www.peripheralinteraction.com/participation.html

1 Background and Motivation

Everyday life is filled with information competing for our attention. While at work, we receive notifications on incoming mail and reminders for the next meeting on top of phone calls and colleagues interrupting. Additionally there may be many more information sources trying to get our attention. Smartphones deliver push notifications whenever a contact writes a message in a chat, the Facebook timeline gets updated, or a tweet is retweeted, to name a few.

Iqbal and Bailey [5] define *notification* as a visual cue, auditory signal, or haptic alert generated by an application or service that relays information to a user outside her current focus of attention. On smartphones, notifications are typically delivered instantly, *e.g.,* when the user receives a message or when a meeting is about to begin.

Instant delivery of notifications has been extensively studied in the context of information workers. One particular challenge is that instantly delivered notifications may interrupt the receiver during other tasks. Czerwinski *et al.* [3] highlight that people find it difficult to return to disrupted tasks after being interrupted by *e.g.,* instant messages, calls, or an engagement with a colleague. They conducted a diary study, with 11 office workers and found that interrupted tasks were not resumed immediately after 40% of the interruptions. As a solution, they suggested to help interrupted users to return to the interrupted task by grouping applications and folders by task.

Cutrell et al. [2] conducted a study in which 16 participants performed a task of searching books in a list organized either by title or topic. They compared performance between search type (concrete title versus abstract topic), notification, and marker. Their results show that notifications make tasks much slower, and their effect is more salient when the user is in the middle of a cognitively demanding task.

Iqbal *et al.* [6] studied the effect of email notification on the desktop computers of office workers. For two weeks, they monitored the application usage of 20 Microsoft employees. They found that the study participants spent roughly one third of their working time in Outlook and one third working in their primary applications. Turning off notifications had no significant effect on this distribution. In average, participants received 3 email notifications per hour, and 25% of notifications led users to immediately switch to email client. When checking Outlook right after receiving a notification, participants switched back twice as fast, thus indicating that Outlook notifications were triggering more opportunistic changes between applications. Outlook is accessed $19 - 22$ times per hour, or roughly every three minutes. In the second week of the study, participants were asked to turn off email notifications. While 8 participants checked emails more frequently, 12 participants checked them less often, which indicates that notifications can influence people in at least two ways: either by creating the urge to respond immediately or by serving as a form of awareness.

Mark et al. [7] studied the negative effects of interruptions by email through a radical approach. For 5 work days, they completely cut off 13 information workers from email usage. Their findings reveal that, without email, the workers multitasked less, spent more consecutive time on tasks, and had a decreased stress level.

Adamczyk *et al.* [1] studied the difference between delivering interruptions during and after completing a task. 16 graduate students had to fulfill different tasks (correct text, write text, web search) on a PC. From time to time, they were interrupted by a full-screen pop-up showing news. The results show that people felt higher workload, measured by the Nasa-Task Load Index, when the interruptions were delivered during the tasks. Fogarty et al. [4] showed that it is possible to predict of human interruptibility with simple sensors .

However, while delivering an email notification can be deferred until the user has completed a task, other notifications, such as calendar entry reminders, have to be delivered on time.

2 Ambient Notifications

With the concept of Ambient Notifications, we pursue the idea of slowly and gently catching a person's attention towards an upcoming notification over time. While the users can stay focused on the primary task, they will slowly be made aware of the upcoming event. According to Matthews et al. [8], (peripheral) displays can target different attentional levels, ranging from pre-attention to focussed attention. The typical notification alarm jumps from absence of directly to full attention. With Ambient Notifications, we aim at moving continuously from pre-attention to focussed attention by slowly increasing the saliency of the displayed cues. This allows users to be aware of the upcoming notification before it is actually due. We assume that this can reduce anxiety and allow workers to finish tasks in time, opposed to leaving them unfinished when e.g. a meeting is beginning.

The challenge to solve is how to convey information in parallel to a work task, in particular how to continuously increase the peripheral display's saliency, so that it slowly becomes more and more present in the mind of the worker. We report on two studies investigating the use of ambient light and vibro-tactile patterns. For ambient light, we provide evidence that by continuously changing the color of an illuminated office wall behind the monitor, we can keep users aware of an approaching appointment. For vibro-tactile patters, we provide first evidence that continually repeated vibration patterns can be consumed in the periphery of attention at all.

2.1 Ambient Timer

With Ambient Timer [9], we created a system to unobtrusively and continuously remind users of upcoming events in an office scenario. Ambient Timer exploits the user's peripheral vision for conveying information on an upcoming task around a computer monitor in a way that the user can still focus on the primary task she is executing on the screen (see Figure 1).

Fig. 1. Ambient Timer illuminating the surroundings of the monitor

We built an RGB-LED frame which we mounted to the back of a monitor. The light emitted by the LEDs was then reflected from the wall the monitor was placed against. Exploring the design space we created continuous light patterns designed to increase obtrusiveness over time (in terms of Matthews' classification we continually increase obtrusiveness to slowly shift from pre-attention to devided attention) in order to slowly make users aware of upcoming tasks while still giving them the chance to wrap up their primary task in a sensible way. We then conducted a lab experiment with controlled light conditions to test our system against traditional reminding techniques. 12 Participants were asked to conduct writing tasks while keeping track of when to finish in time. We found out that our system is at least competitive with traditional reminding techniques such as notification popups or users checking the clock.

2.2 Peripheral Perception of Vibration Patterns

While light has shown to be a powerful modality to design ambient displays, it may have disadvantages if the goal is to keep the interaction private or to avoid polluting the information with more information. The sense of touch, in contrast, offers strong potentials for personal, private information presentation. For example, Tam *et al.* [11] recently presented a timing tool for oral presentations that sends different signals to presenters indicating that 3, 1, or 0 minutes are left before finishing the talk. At each of the intervals, a wristband would start generating different vibration cues, which would "*terminate after an interval, but allowed the speaker to stop them earlier by pressing the wristband*" [11].

As such, these vibration cues can still be seen as interruptions, which attracts attention at three points in time, rather than continuously grabbing attention, as the Ambient Timer.

Hence, we recently explored the question whether continuous vibro-tactile pattern can, at all, become peripheral [10]. For three days, we exposed 15 subjects to a continual vibration pattern, emitted by a mobile devices which was carried in the trouser pocket. The subjects set the vibration to an intensity, where they could barely perceive it. At random intervals, the vibration stopped. In this case, the subject had to take the phone out of the pocket and acknowledge this event by pressing a button. When doing so, they were presented with a short questionnaire to gather subjective feedback. In average, subjects did not acknowledge these events immediately – as if vibration was on their focussed attention –, but rather in 15.2 minutes in average ($\tilde{x}$ = 8.3 min, s = 19.6) At the same time, they reported not to be annoyed by the signal in 94.4% of the events. These results indicate that the stimuli were perceived in the periphery of attention, i.e. outside of focussed attention, while remained aware of it.

While we have yet to investigate how well people perceive subtle, continuous changes in the vibration pattern, this shows that there is an opportunity to use peripheral vibro-tactile displays to deliver ambient notifications.

3 Future Work

In future work, we need to deepen our understanding on how to manipulate perceived saliency of a peripheral display. For vibro-tactile patterns, we just have shown that conveying information in the periphery of attention is possible. What is missing is a way to continuously increase saliency over time. For the Ambient Reminder, we have shown how to increase saliency in a lab study. However, first, informal tests have shown, that in an actual work context other factors appear to be present which influence the perceived salience. Future work hence needs to test these displays in-situ in order to identify these factors, and provide us with an understanding on how to control for them. Taking things a step further future work has to focus on how users will not only perceive information in the periphery of their attention but also control the information device in a way that does not require their focussed attention.

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Peripheral interaction for sports – exploring two modalities for real-time feedback

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Abstract. We believe that sports is a domain that would both provide valuable input to the area of peripheral interaction, as well as benefit from peripheral interaction itself. We present two pilot studies on peripheral interaction for cross-country skiing and golf using vibration feedback and audio feedback respectively. We believe the results of these initial studies are encouraging and aim to pursue the concept of peripheral interaction for the sports domain.
Keywords: Sports, real-time feedback, body movement.

1 Introduction

At her keynote speech at CHI 2010, Genevieve Bell pointed to sports as one of the domains that have been largely forgotten in Human-Computer Interaction (HCI) research, even though work is starting to emerge. We argue that HCI research in sports could contribute to the general problems involved in how to develop interaction models for a range of complex and variable settings where traditional hand-eye interaction is not sufficient, i.e. settings for peripheral interaction. Sports and physical activity provide challenging examples of such settings, and design principles and interaction techniques are potentially transferrable to other mobile domains, such as social and leisure activities in nature.

2 Peripheral interaction in sports

Our take on peripheral interaction comes from the sports domain, where interactive technology has been an integrated part for a long time. However, most technology either support data collection for post analysis such as GPS watches, heart rate monitors, or research prototypes like XC trainer [1], or provide visual interfaces (such as pulse watches) which can be rather difficult to handle during intense sports sessions. There are exceptions in HCI research, e.g. Spelmezan's work on snowboarding [2] and Stienstra's work on skating [3], but they are few. We have conducted initial experiments with tactile and audio feedback during sports to explore how we can design interaction that fits into the activity without breaking the experience or focus of the athletes. We argue that sports technology could benefit from peripheral interaction due to a number of characteristics of sports and physical activity in general:

- many sports involve the whole body and thus requires a mental focus on the activity and the bodily movement making it difficult for athletes to focus on visual user interfaces,
- it is common that sports use physical props such as ski poles, golf clubs, or in other ways occupy parts of the athletes body such as holding the reins during horseback riding or the handle bar of a bike, refraining athletes from holding devices for interaction,
- athletes, both elite and recreational athletes, strongly appreciate the experience of doing sports and prefer not to have their focus on that experience disturbed by technology [4, 5].

This list is in no way exhaustive, but gives some insight on how we see the relationship between sports and peripheral interaction.

3 Experimenting with two different modalities

To investigate how peripheral interaction could be used in sports we have explored two modalities for real-time feedback for two different sports: tactile feecback for cross-country skiing and audio feedback for golf.

3.1 Skiing and vibration feedback

Figure 1: One of our skiers on the treadmill.

The study was carried out at the Swedish Winter Sports Research Centre in Östersund, Sweden. Four Swedish elite skiers participated, recruited by test leaders at the research centre.

The purpose was to explore how vibrational feedback is perceived *during* a sport activity, to what extent it integrates with or disrupt the experience, and how the perception of vibrations are affected by physical activity, and vice versa.

The skiers were equipped with a cell phone strapped around the chest, and skied on a treadmill using different skating techniques at various speeds and inclinations for approximately 30 minutes each, see figure 1.

Different vibration signals were remotely triggered in the phone attached to the skiers' chest. Signals varied in length and repetition. They were all were of the same strength (internal to the phone). Skiers were instructed to acknowledge and comment on the vibrations when they felt them. A post interview was carried out after the skiing session. The whole session was video and audio recorded.

Overall, the skiers were very positive to the idea of vibrational feedback on their skiing technique. They all said they clearly perceived the vibration, and did not describe the experience as intrusive or distracting. Several of them would have preferred a stronger more distinct vibration to make it easier to perceive while focusing on the skiing at higher level of fatigue.

As stated above, the vibration strength did not vary during the session, but the skiers expressed that they had experienced variations in strength. Possible reasons for this could be variations in tension in the upper body as well as variations in focus and concentration in different speeds and techniques, and different levels of fatigue. For instance, one of them said that *you need to be really focused to ski fast, so you block out a lot of stuff.* This suggest that the strength should possibly be increased as skiing intensity increases, but also, that the feedback should not attempt to involve to much information as it may disturb the focus of the skier, thus, potentially being contra-productive.

The skiers believed that vibration feedback on their skiing technique would be helpful during training sessions. In particular, they foresaw using it during high-intensity sessions where they would be especially focused on maintaining a correct technique despite a high-level of fatigue. Moreover, they reported that the skiing technique in general is more in focus at higher workloads since that is when loss of technique is most costly. Consequently, it would be in these situations that skiers would benefit mostly from interactive training support. During slower skiing, the technique is usually less critical so feedback would not be as valuable.

Examples in which they mostly themselves saw the usefulness of real-time feedback were technical details such as the transferring of weight from side to side, keeping the appropriate angles in hips or knees, to help keep specific technique training details in mind, and to be reminded of thinking about technical improvements that they could be working on.

The skiers also saw connections to video analysis, motion capture and other interactive tools that they use to analyze skiing technique. Such tools could be used to reveal important details that need improvement. Combined with real-time feedback mechanisms in the field, these could then be used to prompt skiers to think about those details and keep them constantly in mind during training sessions.

3.2 Golf and audio feedback

For golf we created a system where a sensor attached to the golf club (see figure 2) records accelerometer data which is mapped to real-time audio feedback. The system was implemented as an iphone app using pure data to generate the sound (see [6] for details on the system). Our aim with the feedback was rather to mirror the movement and support golfers in making their own interpretation of the swing than to provide a corrective system, inspired by the Interactional Empowerment philosophy [7].

Figure 2: Sensor attached to the golf club.

We have tested the system in three iterative sessions with experienced golfers to get feedback on the concept of real-time audio feedback on the swing. Typically during testing, users hit four or five golf balls and then been asked to comment on the experience and their understanding of the system, see the setting in figure 3. They tried different sounds and different timing of the feedback. The sessions were video recorded, and system sudio output was recorded in synch with the video.

Figure 3: The setting of our test sessions.

A few themes came up that are interesting for future development and tuning of the system, as well as providing input to the design of peripheral interaction in general:

Interpretation of discrete audio feedback – participants had some difficulty in perceiving real-time feedback since they were focused on swinging and did not have full attention on the feedback. The speculated in this having to do with our audio memory being less trained compared to our visual memory. It might also be the case that audio feedback on a discrete movement such as the golf swing requires more interpretation than a continuous movement such as running or cross-country skiing.

For a continuous movement, athletes can listen for a change in the audio, while for the golf swing they cannot do that.

Timing – from that, we of course came to discuss timing, and also from the second test session provided a mode of the system where the feedback was played directly after the swing instead of during it. We explored different delays to investigate how the timing helps users relate the feedback to the movement and how to make it feel connected to the movement.

Variation in the feedback – participants wanted larger differences in the audio feedback. In the current version of the system they reported that they could hear differences in the feedback between various types of shots, but the differences were quite small and difficult to notice.

In all, participants were positive to audio feedback and has many ideas on how to make it more useful as a golf training tool, for example allowing users to calibrate the system by saving successful shots, creating reversed feedback where the system is silent for good swings and gives audio feedback when the golfer deviates too much, or extending the system to give feedback already on the stance before the swing starts.

4 Discussion

We have presented initial results from a pilot study on the design of peripheral interaction in the form of real time vibrational and audio feedback in sport activities. Overall, this works targets design of services for movement based and bodily engaging settings in the wild. Our overall conclusion is that well designed real-time feedback can be provided for a variety of purposes without disrupting or disturbing the actual sporting experience. Moreover, even though the feedback we provided was relatively basic, the athletes saw usages that went beyond what we had foreseen when designing the study. This points to the possibility of using simple, easy to use devices when designing for a complex settings and activities.

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Animal–Inspired Peripheral Interaction

Evaluating a Dog-Tail Interface for Communicating Robotic States

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Abstract. Animals use emotions for communicating how they feel, e.g., cats arch their back and dogs show their teeth when angry. We believe that allowing robots to communicate using animal-inspired interfaces (e.g., wagging a tail) will help people understand robots' states in terms of affect (e.g., happy, sad, etc.), serving as a clear peripheral awareness channel. This understanding can help people decide when and how to interact with a robot. For example, by appearing scared, a robot can suggest that it needs help. As an investigation of our work, we built a robotic dog-tail prototype and conducted a user study to explore how various parameters of tail movement (e.g., speed) influence people's perception of affect. The results from this study indicated that people interpret tail motions in consistent terms of valence and arousal. We formed an initial set of design guidelines from the results, and further conducted a design workshop by inviting people working as interaction-designers to design tail motions for various states of robots working in different scenarios (e.g., search and rescue), using our design guidelines. Finally, in this paper, we briefly discuss the user study we conducted, present our initial set of guidelines, discuss the steps we took for testing them, and how we improved them so that they can be readily used by Human-Robot Interaction (HRI) designers to convey affective states of their robots.

Keywords: human-robot interaction, animal-inspired interfaces, affective computing.

1 Introduction

In this rapidly advancing field of HRI, many robotic interfaces, designs and prototypes are built to help people in their day-to-day lives (e.g., the iRobot Roomba vacuum cleaner robot cleans the floor while moving). Interaction with robots might be challenging if people are not aware of the present state of the robot, such as low-battery, etc. In addition, it is also important for robots not to bother people too intrusively by giving them status updates, but maintain a peripheral presence to let people know how and when to interact with them. For example, a dishwasher gives an indicator light to show it is working and you can hear the sound it makes while cleaning – it provides peripheral awareness.

Part of the affective computing tradition in human-computer interaction is to incorporate human or animal-like affect and emotion directly into interfaces [6, 8]. For

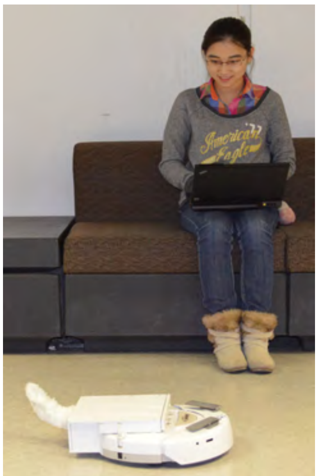

Fig. 1. A person notices the ambient tail state of a cleaning robot

example, a picture frame which uses an ambient color display to communicate emotion between people when they are apart [2]. There is a well-established application of ideas from affective computing to human-robot interaction, where impressions of robotic affect can be used to help users gain high-level state information without requiring them to read complex sensory information [9].

One way of communicating robotic affect is to use animal-inspired interfaces (e.g., dog ears and tails). Zoological research tells us that dogs can convey a broad range of states through their tails, for example, suggesting a happy state by wagging, high arousal or self-confidence by raising, or fear by lowering their tail [1, 3]. In addition, we believe that people understand basic dog tail language such as wagging and high vs. low tail posture. This can be leveraged to understand the present affective state of the robot. For example, when a robot is wagging its tail, it could be considered as being happy (doing its task and does not need attention).

To investigate this, we built a robotic tail prototype to enable an iRobot Create (a disc-shaped robot that resembles a Roomba except that it does not a have a vacuum) to communicate its states (Fig. 1). In addition, we conducted a formal exploratory user study (20 participants) to investigate how people perceived the affect of three tail behaviors: wags - tail moving in horizontal, vertical and circular patterns, static - tail keeps a pose, and discrete gestures such as raising and lowering the tail, which happened at timed points. Movement parameters were systematically varied, e.g., high, medium and low speeds and wag sizes, height and offset of wag, and so forth, to result in 26 distinct tail motions. Participants rated each motion in terms of valence and arousal using Self-Assessment Manikin (SAM), a psychological instrument for rating affective states on Russell's circumplex model of affect [4, 5]: this classifies affect on an arousal dimension (level of energy) and valence dimension (positive versus negative). We found significant results via within-subjects repeated-measures Analysis of Variance (ANOVAs). One such result is Speed by Wag type (as shown in Fig. 2). The results from this study (published in full detail [7]) were used to form a set of prelimi-

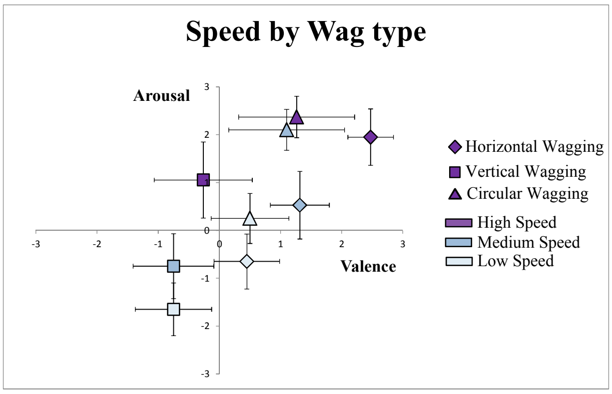

Fig. 2. Average responses (error bars are 95% confidence interval) for low-high speed of horizontal, vertical, and circular wagging. Significant effects ($p<.05$) were found of: a) speed on both valence and arousal, and b) wag type on both valence and arousal. In addition, for valence, vertical wagging was rated significantly lower than horizontal and circular (no significant results were found between horizontal and circular wags). For arousal, all wag types were rated significantly different (for full statistical details see [7]).

nary design guidelines to help HRI designers in conveying the affective states via a dog-tail interface.

Although, we developed our design guidelines, we did not yet know if these could be readily used by the HRI designers and if they can be further improved to be easy to read and use. To investigate this, we conducted a design workshop where we invited people working as interaction-designers and asked them to design tail behaviors for a set of possible states of robots' working in different scenarios (e.g., healthcare robot taking care of people at a hospital)

In this paper, we briefly describe: our preliminary design guidelines, a design workshop we conducted to evaluate our approach, and the results of this workshop. We believe that this is an initial step in exploring how animal-inspired interfaces can be used by robots to communicate affective states to help people decide when and how to interact with them, for peripheral awareness.

2 Preliminary Design Guidelines

We found that the tail was able to convey a broad range of affective states and that people reliably interpreted the tail motions in a consistent fashion. Through informal pilots, we summarized our results into design guidelines for HRI designers for communicating affective robotic states via dog-tail interfaces. Our design guidelines comprised of having each tail behavior in terms of: motion type - parameter (e.g., horizontal wagging - high speed), level of happiness (valence) and energy (arousal) and a descriptive keyword (emotional adjective) conveyed by that particular tail behavior (Fig. 1). Some of the tail characteristics that emerge from our guidelines are:

- A higher tail projects a more positive valence (e.g., happier), and lower tail a more negative valence (e.g., sadder).

- A smaller wag-size projects more arousal (e.g., energetic) and a larger wag-size projects less arousal (e.g., lazier).
- A higher speed projects a higher valence and arousal (e.g., elated) and a lower speed projects a lower valence and a lower arousal (e.g., uninterested).

3 Informal Design Workshop

To investigate whether our design guidelines are easy-to-understand, easy-to-use or need any further improvements, we conducted an informal design workshop where interaction-designers used our guidelines to communicate the states of various robots that might work in different scenarios (e.g., search and rescue.). Through this workshop, we verified that our design guidelines can actually be used for designing the robotic states and asked participants to point out the unclear or confusing parts which might need further improvement.

Our design workshop was conducted with 6 participants (5 males, 1 female) in this way: they were first brought into our experiment space, and we briefly explained the purpose of the workshop and their involvement. Next, we presented 6 robotic scenarios using cue-cards that contained details of robots working in a particular scenario (e.g., domestic environment), and some of the states these robot can communicate (e.g., looking for dirt in case of a utility robot). We used 6 different cue-cards (one for each participant): search and rescue, robot player, robot learner, robotic teacher, security guard robot, domestic robots. We explained our design guidelines to the participants (using a simplified version and a video) and gave them sheets having some pre-listed robotic states such as robot looking for a victim (in search and rescue environment). Next, we asked them to write more states which according to them can possibly be communicated in the given scenario, and asked them to design tail behaviors for all the listed states. In the end, participants proceeded to fill in a post-study questionnaire where we asked them to describe their overall experience, some positive and negative points about our guidelines and suggestions for improving them.

Results. Participants stated that our guidelines as: “very useful,” “thorough,” “easy to follow,” and “helpful.” Most of the participants were able to design the tail behaviors for the listed states; however, only one participant wanted the use of sound and LEDs for one state (a robotic teacher being harassed) and one participant suggested the use of other tail motions not in our vocabulary, such as tail moving in cross-motion and “wobbling” in horizontal wagging. One participant noted that “action gestures [discrete tail actions at given times] should be used for events and not states, since they are not continuous or static like wagging or postures.”

In addition, for improving our guidelines, one participant suggested to use a “reverse-index” to avoid the complexity which might arise as the descriptive keywords were listed according to the categorized tail behaviors. We added an index (lookup index, Table 2a) to our guidelines by assigning a number to each row in Table 1 and made Table 2b) by sorting the descriptive keywords alphabetically and placing the appropriate index value next to them. This improvement is aimed at making the process of designing a tail behavior for a specific affective state quicker and easy to use.

Table 1. Preliminary design guidelines

category	sub-type	parameter	attributes	results: happiness	results: energy	descriptive keywords
continuous wagging	horizontal	speed	low	medium	medium	modest
			medium	s. more*	s. more*	wondering
			high	more	more	joyful or elated
		wag-size	small	–	more	strong, mighty or powerful
			large	–	less	interested
		height	low	less	–	contempt
			parallel to floor	medium	–	awed
			high	more	–	wonder
	vertical	speed	low	lesser	lesser	solemn
			medium	lesser	medium	shy or disdainful
			high	lesser	more	aggressive
		wag-size	small	–	more	aggressive
			large	–	less	selfish or quietly indignant
	circular	speed	low	medium	medium	reverent
			medium	s. more*	more	aggressive or astonished
			high	more	e. more*	overwhelmed
action gestures	raising	speed	low, medium and high	–	–	shy, selfish, disdainful or weary
		height	low and high	–	–	shy, selfish, disdainful, weary timid or fatigued
	lowering	speed	low, medium and high	–	–	shy, selfish, disdainful or weary
		height	low and high	–	–	shy, selfish, disdainful, weary timid or fatigued
static postures		height	low	very less	very less	lonely
			parallel to floor	less	less	fatigued
			high	medium	s. less*	concentrating

*s. more = slightly more, s. less = slightly less, and e. more = even more

4 Future Work

Although we have learnt about how various tail parameters are perceived by people, and how they can be used to communicate affective robotic states, there still remains a question as to how these parameters can be combined with one another. For example, how a tail behavior having large wag size and high speed will be perceived differently from one with a small wag size and low speed. In the short term, we will conduct a formal user study by combining the tail parameters (e.g., speed and wag-size by wag type) to investigate how people perceive the resultant robotic states. Next, we aim at conducting studies to investigate how tail usage relates to type of robot (e.g., humanoid robots like Nao), etc.

Ultimately, this tail exploration is part of a larger program of exploring how other animal-inspired interfaces (e.g., cats ears to suggest aggressive and relaxed behavior, dog-like pawing to exhibit playfulness, etc.) can be used by robots for communicating their states.

Table 2. Reverse-index tables suggested by participants: a) part that attaches to Table 1, and b) part that can be referred by HRI designers to find the tail motion for a specific affective state.

a)

descriptive keywords	lookup index
modest	1
wondering	2
joyful or elated	3
strong, mighty or powerful	4
interested	5
contempt	6
awed	7
wonder	8
solemn	9
shy or disdainful	10
aggressive	11
aggressive	12
selfish or quietly indignant	13
reverent	14
aggressive or astonished	15
overwhelmed	16
shy, selfish, disdainful or weary	17
shy, selfish, disdainful, weary timid or fatigue	17
shy, selfish, disdainful or weary	17
shy, selfish, disdainful, weary timid or fatigue	17
lonely	18
fatigued	19
concentrating	20

b)

descriptive keywords	lookup Index
aggressive or astonished	11,12,15
awed	7
concentrating	20
contempt	6
fatigued	17,19
interested	5
joyful or elated	3
lonely	18
modest	1
overwhelmed	16
reverent	14
selfish or quietly indignant	13
shy or disdainful	10,17
shy, selfish, disdainful or weary	10,17
shy, selfish, disdainful or weary	10,17
shy, selfish, disdainful, weary timid or fatigued	10,17
shy, selfish, disdainful, weary timid or fatigued	10,17
solemn	9
strong, mighty or powerful	4
wonder or wondering	8,2

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Micro Manage Me! – Peripheral Context Annotation for Efficient Time Management

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Abstract. Planning ahead in a world that seems to get more complex every day can be a challenging task. PIM (Personal Information Management) applications try to minimize the mental work load, but are too cumbersome for planning rather insignificant tasks. Due to its static nature, PIM data is prone to unforeseen changes in the real world and therefore require a certain amount of precognition to be planned successfully. Systems exist that use sensor data to derive a rough sense of context in order to proactively show notifications when certain triggers occur. In contrast to that, the proposed system leverages peripheral interaction with physical tags to gain qualitative information on a user's current situation and intents. It uses the data to suggest an efficient order of completion for even small tasks that otherwise would have been regarded too insignificant to plan.
Keywords: Peripheral Interaction, Wearable Computing

1 Introduction

In daily life people are confronted with an ever growing number of things to keep track of: Appointments to attend, mails to read, chores, pledges and things always longed to do.

In order to overcome that complexity of life calendars, to-do lists, memos and PIM (Personal Information Management) software is used. And still a certain complexity of use remains: Techniques like setting up appointments in a calendar to finish tasks at the right time are common practice, as well as meta techniques and self-management practices like GTD (Getting Things Done). But due to their static nature, calendar appointments are prone to unforeseen changes in a user's immediate schedule and hence require a high precognition to be planned successfully. Furthermore, the time overhead for explicitly planning a task (pulling out the device, switching it on, starting the PIM application, entering text, putting the device back) creates a new class of tasks which are considered too insignificant to plan this way. Those are then kept in mind and tend to be forgotten.

Other tasks can only be completed under given preconditions or only in certain places, so they are kept in to-do lists hoping to be read at the right time and in the right place. In order for an automatic system to work proactively in those situations, it has to make assumptions on what the current situation actually is. These systems rely on sensors or external data sources (e.g. position, time, weather forecast) to estimate a user's context and show reminders. But since this context is algorithmically derived from continuous sensor data, it might not correctly reflect the user's real immediate situation, like entering or leaving a room, because of the limited (temporal or spacial) resolution of their sensors.

This demands for a system that can precisely capture the user's context and respond to changes in real-time. This is achieved by incorporating explicit user actions that happen in the periphery of attention while (or even before) the context change is actually happening.

2 Proposed System

Instead of relying merely on context information derived from quantitative sensor data, the proposed system leverages physical tags (bar codes, QR tags and/or RFID tags) that are peripherally scanned in order to gain more qualitative context information on what the user is doing right now or even planning on doing next. Since these context tags, or "ConTags", are explicitly scanned by the user, they are expected to convey a higher feeling of control and less lag than existing proactive task planners that are not triggered by explicit user actions.
ConTags can not only signal that the user is entering a new situation, they can also be used to plan new tasks, like "empty the trash" by scanning the corresponding ConTag that is conveniently placed at the trash can. Having such a fine grain of information on what a user is (planning on) doing –like leaving for work, going to the bathroom or sitting down to do some work– the system can propose an execution pipeline for the most efficient time and order that tasks could be done.

The goal is to create a system that works in the background, capturing information on the user's current and planned tasks, and only springs into attention when it found a task that best fits into the user's immediate schedule, context and free resources.

Wrist worn smart watches, equipped with suitable sensors for reading the context tags peripherally, is used in a first prototype. Data is processed either on the watch itself or on a wirelessly attached smart phone. Notifications are conveyed to the user using the smart watch display, sound, vibration and/or a connected head up display. The optimal mode of notification is still to be evaluated.

Fig. 1. Prototype using acoustic bar codes (top left) and smart watches equipped with a camera (top right) and microphone (bottom)

3 Related Work

A key aspect of the proposed system is the peripheral nature of the interaction, meaning that it is designed to be done in parallel to a main task [8], causing only micro-interruptions or no interruption of the main task at all [2][5]. This attribute sets the proposed system apart from other context annotation systems [6] that require the user's full attention while entering data. The complexity of interaction and hence the mental resources needed to complete the side task strongly affects how well it can be done peripherally or automatically [1], and how it impacts the performance of the main task. That's why ergonomics must also be taken into consideration when selecting technologies for peripherally annotating context.

4 Peripherally Annotating Context

Capturing information on the user's context is a crucial and challenging task for this system. Asking the user to annotate each action using text entry or speech input requires too much engagement and is therefore considered not to be peripheral (happening at the periphery of attention).

Using RFID tags and a body-worn reader seems to be a more subtle approach than text entry, but carrying an always-on RFID antenna near the body might bring power consumption problems as well as raise health concerns. Requiring users to pull out and activate an NFC enabled smart phone for every action they do is not considered peripheral and would impact the intended use of the system. RFID technology can, however, be incorporated into the system for annotating situations where the user's action itself leverages RFID technology, like checking in to work using an RFID pass.

Printed 1D or 2D bar codes, like RFID tags, can be read without physical contact, but require a camera to be pointed at them on every use [7]. This, again, would require the user to pull out and activate a camera phone or wear an always-on camera [3][9] which raises privacy and power consumption concerns. But since bar codes are easy to produce and already incorporated into a variety of products, optical scanning of bar codes can optionally be incorporated into the system for capturing interaction with said products, like “having a reading break” by scanning a book or “having breakfast” by scanning the cereal box.

Another method that combines the advantages of being rather easy to produce and requiring less power than RFID while being always-on, is the use of acoustic bar codes [3]: Like a printed bar code, information is stored in a series of lines, but instead of black lines on white background, acoustic bar codes use grooves that are engraved along the surface of an (3d printed) object. These grooves can be read by scratching a microphone over them and capturing the resulting clicking sounds. The relative temporal distance between these clicks can be decoded back to binary information. Although privacy concerns might still raise from carrying an always-on audio recording device, the system requires only a small amount of power for recording audio and can easily be implemented into wearable devices like smart watches. Swiping the hand across a surface is expected to be a rather non-engaging action, classifying context annotation using acoustic bar codes as a viable peripheral interaction.

5 Intended Use

Having detailed information on the user's context allows a PIM system to better estimate whether a reminder is suitable and worth interrupting the user in the current situation. It can also be used to input new information, like adding tags to business cards or calendars to signal a new appointment when swiping it.

Incorporating this kind of context information might also pose interesting for micro blogging and live journal applications, because ConTags are not limited to carrying ad-hoc information, but can also signal what a user is about to do next, like leaving home, finishing work or meeting other people. This is ideally implemented by adding tags to physical objects that are directly connected to the intended action, like a ConTag on the door handle for signaling leaving the room or ConTags on the bed stand for signaling going to and out of bed.

Using that data the system can, for example, recommend to take out the trash once it has been marked as “full” just in time when the user is about to leave the room or switch all systems to silent mode the second a user gets into bed.

6 Open Questions

By the time this document is written, the prototype is not yet ready for evaluation. Experiments are planned to investigate, among others, the following questions:

- Ergonomics: How does the mere presence of the context annotation device affect users in the completion of a set of common tasks?
- Peripheral Interaction: How does the annotation task impact the completion of the main task? Is it disruptive? Does it cause significant time overhead?
- Optimization: How can the collected data be best used to optimize a user's schedule?
- Future Work: How can other fields of research profit from having timely and accurate context information?

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Appendix: Biography

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The building is the program

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Abstract. We present interaction with a physical building as a hypothetical example of peripheral interaction. The state of the building's windows provides input to an algorithm which produces abstract art as the result of the interaction. This paper assumes the principles of autotopography and Gestalt when considering the use of physical objects for peripheral interaction and computer program definition. By including the Internet of Things in the discussion on peripheral interaction, the latter is no longer constrained to geographically co-located stimuli and responses.

Keywords: internet of things, computer program, peripheral interaction.

1 Introduction

Individuals often modify their environment towards self-determined objectives. For example, a person might turn on a desk lamp or open a window. These examples of individualistic actions are peripheral to the ultimate objectives of reading a book or breathing fresh air. Not only are these actions peripheral, but they are also executed at the periphery of an individual's attention.

The result of an action may be instantaneous (a lit lamp) or gradual (fresher air). A delay may therefore exist between an action and its outcome. Also, an action may manifest itself remotely. An example of an action with both delayed and remote results is when a window is opened at one end of a long passage to allow air in all interconnected offices to be refreshed.

An individual action may affect multiple persons. Conversely, the actions of multiple persons may affect an individual. Therefore, one-to-many and many-to-one relations between actions and results are possible.

In the lamp and window scenarios it would be quite feasible to enhance these physical devices with computational abilities and have them interact with each other when manipulated. Such human-initiated action-reaction, which incorporates computationally enhanced physical devices, is generically called Tangible Interaction (TI) (Baskinger & Gross 2010). However, because the interaction is no longer generic but at the periphery of an individual's attention, it is called Peripheral Interaction (PI).

The Internet of Things (IoT) is an internet-supported action-reaction phenomenon that connects geographically dispersed sensors, computational devices, and actuators. The geographically dispersed sensing and acting dimension of PI can be enhanced by exploiting the IoT to make the relationship between multiple actions and multiple reactions even more multifaceted. The almost unlimited geographic distances which IoT affords to PI can only be fully realised if Hornecker's space-centered view of TI (Hornecker & Buur 2006) is applied to PI. We call TI which includes both PI and IoT, space-centered peripheral interaction (SPI).

In this paper we explore SPI by considering an individual's hypothetical peripheral interaction with a physical building. Here, the building is computationally enhanced and receives input from its windows, and reacts by producing abstract two-dimensional art.

This paper approaches SPI from the theoretic standpoints of autotopography and Gestalt. Section two provides the theoretical perspective to our approach. Section three discusses, with examples, objects and their relationships. In section four we consider the potential relationship between objects and computer programs. Section five concludes.

2 Autotopography and Gestalt School of Thought

Autotopography (**auto=one's own** (from the Greek *auto*), and **topography=place** (from the Greek *topo*)) is the behaviour a person exhibits by adjusting the physical environment to "*…construct a sense of themselves*", through arranging physical objects to create "*a physical map of memory, history and belief.*" According to Hoven, external memory is a subset of distributed cognition, and one of the functions served by external memory is to reduce memory load by facilitating memory recollection (van den Hoven 2004).

Petrelli (Petrelli et al. 2008) studied, amongst others, (1) what types of objects persons used for autotopography, (2) the way in which these objects were used, and (3) what made these objects suitable for this purpose. These studies revealed that the appearance of the physical objects was not always important, but rather the "time or emotion" it represented.

As far as the use of generic objects to recall memory is concerned, Hoven states that these are not ideal for this purpose because they all look the same. Hoven continues by suggesting that personal objects would be better served for this purpose "*…because the mental model is created by the user herself and not imposed by the system.*" Yet Hoven states that a single object can have different meanings to different persons. It thus seems plausible that a generic object could be used to recall memory if the person has emotion attached to the object.

The Gestalt theory of perception states that sensations are not perceived in isolation, but are "*…assembled into perceptual experiences… called a Gestalt*" (Kasschau 2003, p224). According to the Gestalt school of thought, the brain constructs perceptions from sensations based on the principles of proximity, continuity, similarity, simplicity, and closure (Kasschau 2003, p224).

3 Objects and Their Relationship

We consider computer programming with the premise that the spatial relationship between a set of objects carries information for the person who has placed and oriented the objects.

3.1 In Physical Space

A physical artefact can be considered an 'object' or a 'thing', depending on its context. When an artefact is considered in isolation from its surroundings, the artefact is classified as a 'thing' but when it is considered in context with its surroundings it is classified as an 'object' (Latour 2004, p233). Objects 'gather' meaning because of their relation to other 'things' (Boradkar 2010).

3.2 In Print

The lines, colours, and curves of a drawing are at times interesting to some in that these two-dimensional prints contain a story (Suda 2010). This is also called "visualisation" of data and has become the subject of study for some. It has also been suggested by some that a "language of charts and graphs" exists (Suda 2010). The purpose of the visualisation graphs and charts is to convey the complicated messages contained in a data set to the observer in a simple way. Suda compares the graphs that tell a story to the reader to the story is carried by text, for example in a novel, or the story conveyed to the observer with a cartoon or painting. Examples are respectively that of a painting, a plan for an electrical circuit, and a building plan for a dwelling. These are interpreted by the observer. Depending on the observer's training and cultural background, the three examples will each convey some message to the observer. The nature of the message could range from being of no interest or value, to one of instruction/informative, to philosophical. The message can be both subjective and objective at the same moment in time, depending on the observer and the circumstance it which it is being observed. For example, the painting shown here could elicit a philosophical discussion amongst the group of artists viewing it at the Musée du Louvre in Paris. However, for a young electronic engineer it may have very little value, simply representing something a renowned person created long ago. The converse could be stated about the electrical diagram when viewed by the young engineer and the group of artists; it has little value to the artists, but to the engineer it represents a very specific assembly of physical objects that can transform an electrical signal.

Dondis (Dondis 1973, p17) explains that "*when we see…it is a multidimensional process…*", that is, we see so many things at the same time and "*imposing…compositional forces*" on what we are seeing. We are thus not looking at an image as one would read a manuscript line by line, but taking notice of the complete image all at once and deriving the "*compositional forces*" therein. Dondis states that visual literacy is acquired through training and learning, and this explains why an electrical engineer, artist, and architect would identify with ease respectively a electrical circuit diagram, the message in a painting, and the designed function of a building.

3.3 In Art

The previous subsection considered patterns created by engineers, for engineers. Here, we consider patterns created by artists.

Artists sometimes personify art; objects depicted in a pencil drawing on paper has been described as "*a carafe with mugs as bodyguards...*" (Clement & Kamena 2000). This supports our thinking that to the observer it seems that there exists a relationship between objects. In the example of Clements, there exists a relationship between the carafe and mugs. The relationship is that of a master and those whose function it is to protect the master. Here the carafe is the master, and the mugs are the bodyguards. Next we consider how this relationship may be made clear by adding another dimension to the relationship: the dimension of forces. **Fig. 1** depicts Clement's description of the bodyguards as a force diagram. In the diagram, the red objects 'guard' the yellow object from approaches by the blue objects. 'Force lines' emanating from the red and blue objects indicate the direction on strength these 'forces'. The length of the force line is proportional to the magnitude of the force. The solid force lines are repelling forces, and the dashed force lines represent the force propelling the object in the direction of the arrow. The solid line linking objects indicate the bodyguard/master relationship.

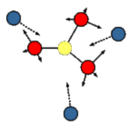

Fig. 1. 'Bodyguards' (red) repel 'invaders' (blue). Inspired by Clement (Clement & Kamena 2000).

Fig. 2. James Stirling. New State Gallery, Germany (Fichner-Rathus 2012, p28)

4 A relationship between Objects and Computer Programs

Art on canvas, and engineering drawings, may also include straight lines and geometrical symbols.

Our research considers the extension of the two-dimensional relationship between art, engineering, and computer programs to the possible three dimensional correspondences between art, engineering, and computer programs.

The vertical lines in Stirling's New State Gallery architecture (**Fig. 2**) may remind one of the sequential and uninterrupted execution of instructions in a computer program. The multiple vertical lines may represent multiple simultaneous streams of code being executed in a computer program, commonly known in the field of computer science as parallel execution of multiple program threads.

This is just one discussion of what the architecture might represent if it were to be interpreted as the logic for a computer program. It would be for the designer of the physical language to define the meaning of the physical artefact.

4.1 A relationship between Architecture and Computer Programs

We now consider how architecture could be interpreted as a computer program.

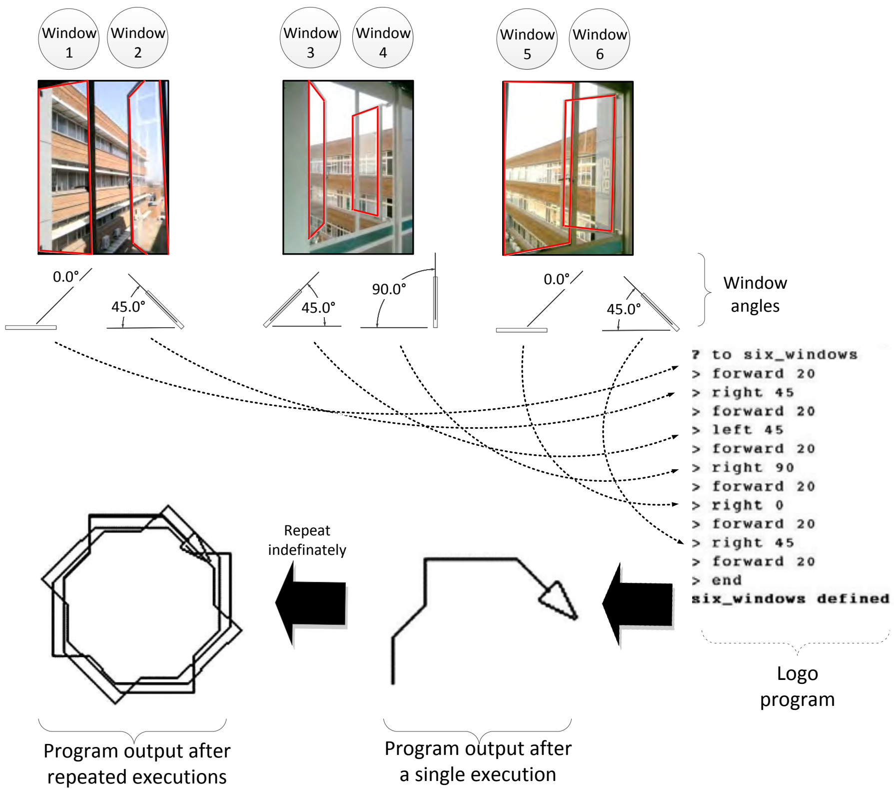

Fig. 3. Window positions translate to Logo program parameters.

Consider an array of windows (**Fig. 3**, top) and assume that the state of each window can be interpreted as a computer program instruction. Using this approach we anticipate that an office complex could be regarded as a computer program. We illustrate this concept using indoor photographs of windows along a passage linking two sections of an office complex. In this example some of the windows are fixed and others can be opened. The angle to which a particular window is opened is determined by the user and can vary between zero degrees and 90 degrees. Let's make the assumption that this angle represents the angle a Logo turtle (Abelson & diSessa 1980) turns and each turn is followed by 20 units of forward motion.

We use the following mapping: if the window opens to the left as per the user's point of view, the Logo turtle will turn to the left. The converse is also true. We do not yet have a means to instruct the Logo turtle to move forward or backward. To add this ability to our bag of instructions, let us agree that the turtle moves a fixed amount forward immediately after a turn instruction has been executed. As we do not have a mechanism to state how much the Logo turtle should move forwards, let's make this an arbitrary constant of, say, 20 units. The angle and direction which the Logo turtle rotates can simply be the same angle and direction in which the window has been opened. We further assume the Logo pen is always down. **Fig. 3**, bottom left, is the result.

5 Conclusion

We have explained why peripheral interaction can be considered to be a special case of tangible interaction, and how the inclusion of the Internet of Things enhances the spatial quality of interaction. Spatial Peripheral Interaction (SPI) was used to describe the resultant interaction form. The potential of SPI was illustrated by means of a hypothetical computationally enhanced physical building which produces abstract art in response to the status of its windows.

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