Do Not Disturb: Physical Interfaces for Parallel Peripheral Interactions

Fernando Olivera, Manuel García-Herranz, Pablo A. Haya, and Pablo Llinás

Dept. Ingeniería Informática, Universidad Autónoma de Madrid
C. Fco. Tomás y Valiente, 11, 28049 Madrid, Spain
{Fernando.Olivera, Manuel.GarciaHerranz, Pablo.Haya, Pablo.Llinas}@uam.es

Abstract. Interaction is, intrinsically, a multi-thread process. Supported by our various senses, our ability to speak, and the structure of our body and mind we can get simultaneously involved in multiple interactions, using different resources for each of them. This paper analyses natural interactions and the impact of using parallel channels in peripheral interactions. Applying a similar approach to human-computer interaction, we present a Tangible User Interface proof of concept to analyze the advantages and weakness of parallel interaction in computer-based systems. To this end, two tangible applications -to control the profile status in social networks and to control an Intelligent Room- are compared to their usual graphical counterparts, presenting the results of a user study and analyzing the implications of its results.

Keywords: tangible, subtle interaction, calm computing, fiducial marker, peripheral interaction, parallel interaction.

1 Introduction

A guy is in a coffee place reading the newspaper with an almost-empty mug on the table when the waitress arrives ready to fill up his mug. With this scenario let us consider three possible reactions. 1) He turns to the waitress and says “No more, thanks”. 2) He looks up to her for a second, pulling his lips together in a soft forced smile and barely shaking his head while slightly raising the fingers of his right hand. 3) He continues reading the paper while softly placing a hand over the mug (in some regions, patrons use coasters placed on top of their cups to indicate waiters that they do not wish to have a refill). What do these reactions have in common? What do they differ in? While they clearly share a common message: “No more coffee”, they differ in the interaction channel used to communicate it: direct and explicit in 1), subtle in 2) and 3). The third reaction, in addition, takes advantage of a purely physical channel, freeing the interaction of almost any visual load, thus allowing the customer to use this resource to continue reading the newspaper. This article focuses on the 3)-like interactions (physical simple interactions): those codifying the semantics of simple messages in a physical action over a physical object.

Calm Technology [1] posed a new way of information technology that “engages both the *center* and *periphery* of our attention, and in fact moves back and forth between the two”. In the same way, we consider it ground of a new interaction technology that can move back and forth between the center and the periphery of our interaction too. Using *periphery*, as Weiser and Brown, “to name what we are attuned to without attending to explicitly” [1].

Following the path opened by Matthews et al. [2], we have previously explored Subtle Interaction [3]. Rather than focusing on information visualization, Subtle Interaction uses a concise piece of information to build up a dialog upon context. Peripheral Interaction explores an analogous concept from a different perspective: How much of our attention do we put into the interaction itself? Both are meant to be fast but for different reasons. In the former, the message to be send is short (i.e. a concise piece of information to trigger a richer dialog), thus the interaction is brief. Nevertheless, while winking to our loved one might be a brief act, our interaction is (and we want it to be) completely focused on it. Conversely, Peripheral Interaction is brief because our interaction focus is somewhere else and, as in the “hand over the mug” reaction, we want to deal with it without strongly affecting the main one.

Our five senses are naturally designed for different types of interaction. Thus, our binocular stereoscopic vision is designed to focus on a particular object (contrary to the wide range monocular vision of most animals of prey) while our somatosensory system is distributed all along our body to simultaneously collect diverse stimuli from different sources. Moreover, different parts of our brain control and process each of them. Contrary to Edge and Blackwell [4] who already used the term to explore and “exploit the affordances of physicality to facilitate the *engaging user experiences*”, we pursue a parallel non-engaging interaction channel. Thus, instead of looking for an extra channel to enrich a particular domain of interaction, we pursue a parallel one for users to deal with simultaneous domains, allowing them to naturally distribute the interactions among the channels according to the nature and importance of the tasks.

The potentials of this parallel architecture are lost when most human-computer interfaces are designed for our vision (and bits of hearing) and thus collide and crowd into a single channel. Thus, as human-computer interactions expand through our life, penetrating every bit of it (e.g. planning, social networking, leisuring, working or communicating), the HCI community faces the problem of dealing with itself: how many of our thoughtfully designed interfaces coexist in user’s daily life. In this sense, it is critical to reduce the interaction overhead where it is not needed nor wanted. For instance, a status update in Skype -not to be interrupted in the middle of a movie- requires a considerable amount of interaction (i.e. opening Skype’s window and selecting from a dropdown menu) compared to leaving a nearby phone off the hook. This overload can be reduced either by cutting down the interaction needed or by minimizing the impact of it, transferring it to underused interaction channels to reduce the load of overused ones.

Physicality opens up a parallel interaction channel and thus, due to the nature of our somatosensory system, extra threads for interaction that may require low attention. Therefore, it allows performing tasks concurrently as well as to move some of them to an interaction periphery. In addition, physical objects have a strong and inherent directedness both for performing actions and retrieving feedback. As when hanging a “Do not disturb” sign at the room’s door, physical objects stress a direct mapping between commands and actions and stay there to remind us their state.

This article explores the possibilities of Peripheral Interaction through physical and simple actions.

2 Peripheral Interaction through Physical and Simple Actions

To study physical simple interaction we have augmented physical objects using Fiducial Markers (FM) -i.e. 2D-codes, designed to improve the accuracy of automatic image recognition systems- to create a special tangible object or PolyTag (i.e. polyhedrons with FM printed on their faces) as a proof of concept for Peripheral Interaction. As multi-faced dices, PolyTags are human-computer interfaces in which half of their faces hold a human-readable command (a word or an icon) while their opposites hold a FM to be read by the computer (see Figure 1).

Thus, PolyTags are objects that can be both interpreted by humans and computers as in Magic Cards [5] in which this kind of systems are used to control domestic robots. The number of possible commands a PolyTag can hold is determined by half its number of sides: opposite to each human readable icon there is a FM to be read by the camera embedded in the table when the human readable side faces up to the user.

Since the camera can recognize the FM identity, location and orientation, interaction can be further enriched with placement and manipulation information. Additionally, in a rear projected tabletop, dynamic feedback can be shown to the user in the form of halos or associated labels.

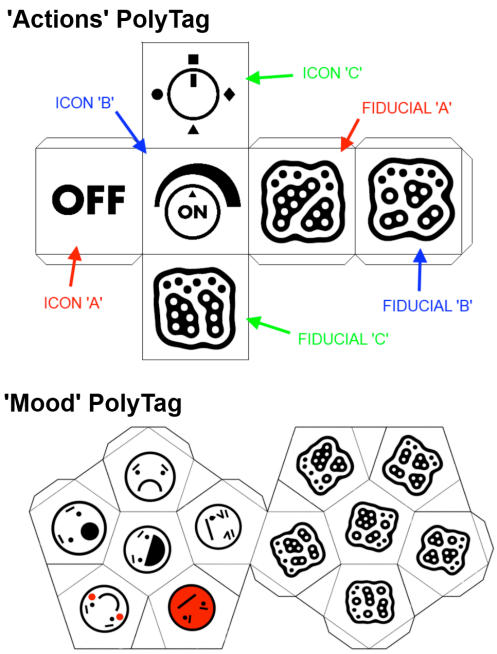
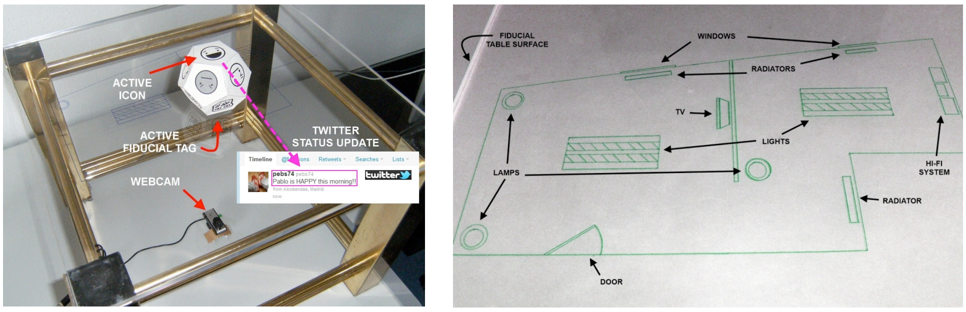


Figure 1. PolyTags are easily printed and constructed, and can be personalized with user-selected actions.

Our proof-of-concept prototype consists of a glass coffee table, a webcam and a CPU (see Figure 2 a.). The webcam is positioned upward under the table to capture any object on the table through the glass surface.

When a FM is identified, a TUIO [6] message is sent to the end-user application using the reacTIVision [7] computer vision framework. Using this framework we developed two case studies for social networking and ubiquitous control respectively. The former is intended to explore Peripheral interaction as an unobtrusive mean of parallel control. Mimicking the "hand over the cup" reaction, we analyze fixed and simple physical interactions as parallel channels for controlling out-of-focus applications, in this case controlling the status of our social network profile. The latter explores the potential of this type of interfaces to perform more complex interactions. Using an Intelligent Environment as scenario, we analyze tailored physical actions enriched with movement information to control home appliances.



(a) (b)

Figure 2. (a): The fiducial table has a clear surface and the webcam is positioned below looking upwards. (b) The intelligent environment schema drawn on the table contains a representation of all configurable devices. To interact with a device, the 'Actions' PolyTag must be placed on top of its representation.

2.2.1 Social networking

The 'Mood' PolyTag (see Figure 1), a twelve-sided dodecahedron, is intended to set the status of social networks. Each human readable face holds a different emoticon expressing a feeling (happy, upset, angry…). When placed on the table the status of different social platforms such as Twitter, Facebook, or Buzz is updated according to the emoticon facing up. This task, usually requiring to open the social app on a mobile phone and typing in a message, is performed using the 'Status' PolyTag with minimal attention, thus minimizing the loss of focus suffered in the main activity (e.g. talking, reading or watching TV). Since FM are responsible for the actions, different users can have their own replica of the 'Mood' PolyTag. While these PolyTags will share the same icons, their different FM will allow the system not only to identify the action to be performed but also the user commanding it.

2.2.2 Ubiquitous control

The 'Actions' PolyTag is a 6-sided dice to control the environment. For this prototype, a schematic representation of the intelligent space is drawn on the table's surface (see Figure 2.b) showing all interactive elements that can be controlled with the PolyTag. The PolyTag allows for three actions: 'Power', 'Select' and 'Off'. Power and Select are movement enriched actions, allowing respectively to turn the volume/intensity up and down and to change the channel/mode by rotating the PolyTag once placed on top of the representation of the element to be controlled.

As an example, to turn on the TV and search for Channel 4, the user will place the PolyTag, with the "Power" face looking up, on top of the TV icon of the table. On posing the PolyTag, the TV will turn on, and by rotating it the volume is adjusted. Then, turning the PolyTag so the 'Select' face looks up, the user can channel-hop by rotating it as when adjusting the volume. When similar operations are conducted over other elements such as heaters or lights, the Power and Select operations adapt their meaning to the them thus controlling temperature or light intensity and changing between cooling and heating modes or selecting light color.

Integration with the intelligent environment is achieved using the context-based architecture for intelligent environments described in [8].

3. Evaluation

We have performed a preliminary experiment to show how tangible interfaces can be used to reduce the attention load of certain tasks. The experiment was conducted with 6 males and 4 females from 23 to 28 years old. The population was chosen so all of them had programming skills and experience using Internet and social networks.

We choose a within-subjects design in which each participant had to perform an attention demanding task interrupted with a secondary task that had to be accomplished using two different user interfaces presented one after the other in random order. Subjects were therefore asked to count how many times a particular vowel appeared in a given text to force them to focus into an attention demanding task. While counting vowels, they were asked to carry out some extra task related to the foretold scenarios such as changing their status in Twitter or controlling an intelligent environment (turning on/off the lights, browsing TV channels…). These interruptions were randomly distributed over each trial and accomplished using either the tangible interface proposed in this article or a graphical user interface (a browser logged in a Twitter account and a web based application for controlling the smart home [9]). The order in which each participant performed the trials was counterbalanced. In addition, to minimize the learning effects, different texts of similar complexity were used in each trial.

As dependent variables both error rate (ratio between errors and number of words) and performance (word per seconds) were measured (see Table 1).

Since data were non-normally distributed, the Wilcoxon Signed Ranks Test for related samples was chosen. The analysis shows that participants make marginally significant fewer errors in the main task (counting vowels) when using the tangible interface than when using the GUI, $Z(10) = -1.886$, $p = 0.059$, $r = 0.242$. Additionally, the performance in the tangible trial was significantly better than in the GUI ones, $Z(10) = -2.514$, $p = 0.012$, $r = 0.974$.

Table 1. Experiment results of the ten subjects including the mean and standard deviation of the whole group.

Subject	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	Mean (Std. Dev)
Fiducial Version											
Error Rate (%)	0	3	1.5	5	1	0	2	4	6	1.5	2.4 (±2.1)
WPS	1.4	0.7	3.3	1.1	1.1	0.8	1.3	1.0	1.4	1.6	1.4 (±0.7)
GUI Version											
Error Rate (%)	6.4	0.6	10.4	6.9	1.7	1.7	2.9	7.5	5.2	2.9	4.6 (±3.2)
WPS	1.4	0.8	2.5	0.9	0.9	0.5	1.1	0.9	1.2	1.3	1.2 (±0.6)

Both GUIs were selected to require a similar amount of user's interaction time compared to the PolyTag interface. On the other hand, the attention load they require pays its price in the number of errors users make in the main task since users lose their concentration more easily when using the GUI interface than when using the tangible one. While the two scenarios present an increasing degree of complexity in the interaction, further investigation is required to study the limitations and implications of complex interactions in user's attention.

4. Related work

HCI researchers have previously explored subtle interaction in peripheral displays [2][4]. These ambient displays have shown how computers can give information in a subtle way. Similarly, as we have discussed throughout this article, we believe that users should be also able to give simple orders to computers in an unobtrusive way, allowing them to command simple actions while keeping their focus in other tasks.

Fiducial-based approachs have been previously used in the field of Augmented Reality [10] as well as for transforming physical objects into tangible interfaces (usually as physical icons, called phicons in the field of TUI). D-Touch [11] showed how to develop low cost tangible interfaces for musical applications using fiducial tags. Other musical systems have used other passive technologies such as RF tags [12 or Near Field Communication (NFC) to send messages (usually an ID). While RF tags are considered a low cost solution, they are not as affordable as printed-based technologies such as Fiducial Markers. In this sense, further research in tabletops explores the use of Fiducial Markers, usually as a way to easily integrate object recognition in GUI, as shown in the reacTIVision framework [6], which was also developed to explore musical tangible instruments.

Besides music, Fiducial Markers have been previously used to control information in ambient displays of intelligent environment too [13]. Nevertheless, our contribution follows a different direction looking for subtle ways to communicate with computers rather than for subtle ways in which they communicate with us.

Finally, tangible interfaces' relationship with social networks has been also explored in the form of simple peripheral displays [14] or through limited interfaces [15]. Rather than aiming to retrieve information from or interact with our digital social networks in enhanced ways [16], we seek new channels to interact with them, channels that can parallelize some of the simple interactions they require (such as updating our status) with other concurrent activities. This kind of parallel channels have been briefly explored in art and school projects using wearable technologies, such as shoes sending information about our steps to Twitter [17] or registering events on Facebook through RFID tagged shoes [18].

5. Conclusions

This paper analyses the diversity of interactions in our nature and, focusing on Peripheral Interaction, aims to provide a similar approach to human-computer interaction. Exploiting the physicality of tangible user interfaces, we explore the necessity and means to enrich human-computer interaction with parallel threads to allow peripheral interactions to take place without strongly affecting our focus.

We have argued the benefits and limitations of physicality and based our design on the directedness of its actions and feedback (i.e. straight and explicit commands and constant feedback of its state).

We have then presented the PolyTags that, using Fiducial Markers, remove any need for power supply reducing both unit and maintenance costs. Additionally, they are easy to use and modify and can be built from paper or cardboard at a very low cost thus being a customizable and versatile solution. Since the same icon can be assigned to different Fiducial Markers we are able to thus preserve a human-readable image in different PolyTags while allowing the computer to distinguish between them., Ttherefore, as an example, members of a family can each use a 'Mood' PolyTag in which emoticons are constant while the system is able to recognize whose its owner.

Focusing on the input capabilities of Peripheral Interaction rather than on the output ones we have built two demonstrators: a) a status updater for social networks, and b) a tangible UI for controlling an intelligent environment. We have evaluated them as a mean for parallel interaction in terms of how they affect the effectiveness (number of errors) and efficiency (time spent) of a concurrent task and compared this results with traditional GUIs. The results show a clear increase in the effectiveness of the concurrent task while a small improvement in terms of efficiency. While the low correlation in the effectiveness requires of further experiments to make stronger assertions, the results incline us to think that the parallel channel provided by the PolyTags helps in reducing the attention needs, thus improving the effectiveness and efficiency of the main task. Additionally, we hypothesize this attention reduction is due to taking advantage of an underused interaction channel (somatosensory system) to reduce the load of the main one (sight), since while the identification of the action to perform remains visual, positioning (contrary to the mouse cursor of the GUI approach) is tactile-supported.

This article has shown that through physical interaction we can open natural interaction channels to distribute the interaction load of simultaneous tasks, resulting in an equally fast interaction with less lost of attention.

Acknowledgments. This work has been partially funded by the following projects: ASIES: Adapting Social & Intelligent Environments to Support people with special needs (TIN2010-17344), Vesta (TSI-020100-2009-828) and e-Madrid (S2009/TIC-1650).

References

1. Weiser, M., Brown, J.S.: Designing calm technology. In: PowerGrid Journal, 1(1): pp. 75–85 (1996)
2. Matthews, T., Dey, A.K., Mankoff, J., Carter, S., Rattenbury, T.: A toolkit for managing user attention in peripheral displays. In: 17th annual ACM Symposium on User interface software and technology, pp. 247–256. ACM (2004)
3. Olivera, F., García-Herranz, M., Haya, P.A.: Subtle Interaction for Ambient Assisted Living. In: II International Workshop on Ambient Assisted Living, IWAAL 2010 (CEDI 2010) (2010).
4. Edge, D., Blackwell, A.: Peripheral Tangible Interaction by Analytic Design. In: TEI'2009, pp. 69–76 (2009)
5. Zhao, S., Nakamura, K., Ishii, K., Igarashi, T.: Magic cards: a paper tag interface for implicit robot control. In: CHI '09. ACM, pp. 173–182 (2009)
6. Kaltenbrunner, M., Bovermann, T., Bencina, R., Costanza, E.: TUIO: A protocol for table-top tangible user interfaces. In: 6th Int'l Workshop on Gesture in Human-Computer Interaction and Simulation (2005)
7. Kaltenbrunner, M., Bencina. R.: reacTIVision: a computer-vision framework for table-based tangible interaction. In: TEI'2007, pp. 74. ACM (2007)
8. Haya, P.A., Montoro, G., Alamán, X.: A prototype of a context-based architecture for intelligent home environments. In: International Conference on Cooperative Information Systems (CoopIS 2004), LNCS, volume 3290, pp. 477–491 (2004)
9. Gómez, J., Montoro, G., Haya, P.A.: iFaces: Adaptative user interfaces for Ambient Intelligence. In: IADIS International Conference on Interfaces and Human Computer Interaction (2008)
10. Rekimoto, J. Ayatsuka, Y.: CyberCode: designing augmented reality environments with visual tags. In: DARE 2000 on Designing augmented reality environments. ACM (2000)
11. Costanza, E., Shelley, S.B., Robinson, J.: D-touch: A consumer-grade tangible interface module and musical applications. In: HCI'03, pp. 8–12 (2003)
12. Patten, J., Recht, B. Ishii, H.: Audiopad: a tag-based interface for musical performance. In: New interfaces for musical expression, National University of Singapore (2002)
13. Bovermann, T., Hermann, T., Ritter. H.: A tangible environment for ambient data representation. In: 1st International Workshop on Haptic and Audio Interaction Design, volume 2, pp. 26–30 (2006)
14. McPhail, S.: Buddy Bugs: A Physical User Interface for Windows Instant Messenger. In: Western Computer Graphics Symposium (Skigraph'02) (2002)
15. Peek, N., Pitman, D., The, R.: Hangsters: tangible peripheral interactive avatars for instant messaging. In: TEI'2009, pp. 25–26. ACM (2009)
16. Kalanithi, J.J., Bove Jr. V.M.: Connectibles: tangible social networks. In: TEI'2008, pp. 199–206. ACM (2008)
17. O'Nascimento, R., Martins, T.: Rambler, http://www.popkalab.com/ramblershoes.html
18. Lemhag, H., Naslund, M., Andersson, A., Bengtson, K., Madonia, P., Gustafsson, B.: WESC Karmatech Cocept, http://projeqt.com/piermadonia#lsi8859ci2134q