Exploring the Design Space for Situated Glyphs to Support Dynamic Work Environments

Fahim Kawsar[1,2], Jo Vermeulen[3], Kevin Smith[1], Kris Luyten[3], and Gerd Kortuem[1]

[1] Lancaster University, UK
{kawsar,kortuem}@comp.lancs.ac.uk, k.smith@lancaster.ac.uk
[2] Bell Labs, Belgium
fahim.kawsar@alcatel-luncet.com
[3] Hasselt University, Belgium
{jo.vermeulen,kris.luyten}@uhasselt.be

Abstract. This note offers a reflection on the design space for a situated glyph - a single, adaptive and multivariate graphical unit that provides in-situ task information in demanding work environments. Rather than presenting a concrete solution, our objective is to map out the broad design space to foster further exploration. The analysis of this design space in the context of dynamic work environments covers i) information affinity - the type of information can be presented with situated glyphs, ii) representation density - the medium and fidelity of information presentation, iii) spatial distribution - distribution granularity and placement alternatives for situated glyphs, and finally iv) temporal distribution - the timing of information provision through glyphs. Our analysis has uncovered new problem spaces that are still unexplored and could motivate further work in the field.

1 Introduction

In the field of information visualization, a *glyph* is a single graphical unit designed to convey multiple data [15]. Different parts of the representation or different visual attributes (e.g., shape, size, colour) are utilized to encode different values. One early example was shown by Chernoff [5] who represented multidimensional data through different attributes of human faces, e.g., a nose, eyes. In contemporary literature, researchers have used glyphs to represent different attributes of documents [14] or for visualising software management data [16]. Due to their intrinsic capability of representing multiple variables with a single graphical representation, we see opportunities to explore the use of glyphs for exposing salient information in a subtle fashion in dynamic work places. Recent studies have shown that there is a clear need to present task-centric information in demanding work places, such as hospitals or industrial plants [1, 2]. Consider the situation depicted in Fig. 1(a), where a nurse can choose to perform multiple activities with multiple patients and objects. She might decide to use saline water with patient one or patient three, or she might decide to support patient two instead. In each case, she needs information that matches her activity. As existing studies have shown, medical personnel would benefit most from having specific information available (e.g., guidelines) about their *current activity*, linked to *equipment* and *patients* that are relevant to this activity [2, 3].

K. Lyons, J. Hightower, and E.M. Huang (Eds.): Pervasive 2011, LNCS 6696, pp. 70–78, 2011.

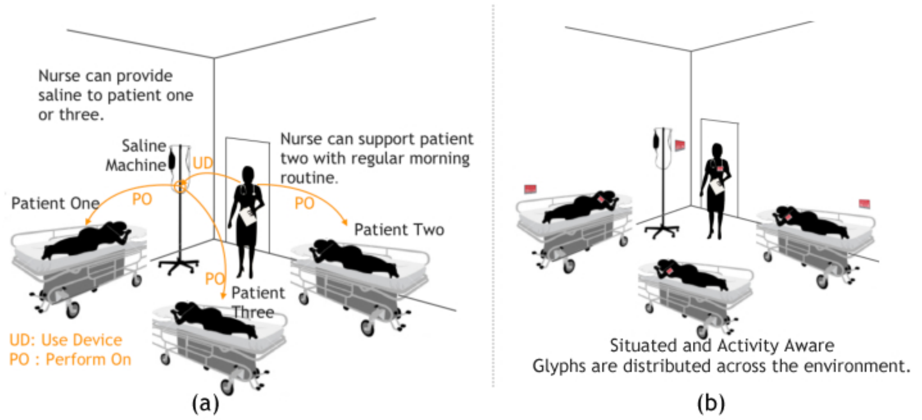

Fig. 1. A Hypothetical Nursing Home Scenario with and without Situated Glyphs

To this end, we envisage that glyphs provide an interesting design alternative to present real time in-situ information to support multiple interleaved activities involving multiple individuals and different types of equipment in complex workplaces. Accordingly, we have devised *situated glyphs* as graphical units that are situated in time and space – they are visual representations of activities, and are adaptive, mobile and replaceable. Fig. 1(b) envisions the same situation as explained above, but here the environment is augmented with multiple situated glyphs. In this case, when a nurse approaches a certain type of equipment or a patient to perform an activity, corresponding glyphs show the information that is relevant to that activity. One of the key functions of situated glyphs is to help people *discover* the activities that can be performed in a given space, at a given time with the devices and objects at hand.

There has been a lot of work on information provisioning through ambient displays – often embedded in interesting artistic objects or everyday artefacts, distributed across the environment and providing a constant stream of peripheral information [6, 10, 11]. Information presented through ambient displays is always interesting, sometimes useful but rarely vital. In contrast, our focus with situated glyphs is activity-centred. We aim to support (both cognitive and physically) demanding real-world activities, such as nursing tasks in a hospital, by mapping visual representations of activity-specific information to the physical environment using situated glyphs.

In what follows, we investigate different design cardinals for these situated glyphs which we consider as the main contribution of this note: *information affinity* (Sect. 2.1), *representation density* (Sect. 2.2), *spatial distribution* (Sect. 2.3) and *temporal distribution* (Sect. 2.4) , respectively addressing the content, appearance, placement, and timing aspects of situated glyphs. We also present an example design of a situated glyph to illustrate the concepts. Finally, we conclude by pointing to the unexplored problem space that might foster future work in this field (Sect. 3).

2 Situated Glyphs: Understanding the Design Space

Situated glyphs are visual representations of physical activities and are adaptive in a sense that they move and change their appearance to match the activity at hand. They are distributed in the environment through *place-holders*, i.e., each place holder can present different glyphs at different points in time. Typically, glyphs are mapped onto an environment by means of small embedded networked displays. Due to these characteristics, situated glyphs put forth a number of design questions. Ware [15] gives a basic background on standard glyphs emphasising on finding the right encoding mechanism to encode information into symbols. Drawing on his theory in the context of pervasive computing environments, we observe that there are four design cardinals that need to be considered for physical embodiment of these situated glyphs. These design cardinals address four basic questions - *what* information to present in situated glyphs, *how*, *where* and *when*? In the following sections, we discuss these questions and present a broad perspective on the design space of situated glyphs.

2.1 What: Information Affinity

Information Affinity describes the type of information that is substantial to maintain the operational efficiency and consistency of a dynamic work environment, i.e., it addresses the "What" aspect of situated glyphs. One way to address this information affinity is to look at the activity patterns in the work environment to expose the basic and critical information needs. Considering this paper predominantly focuses on the health care domain, in this section we will center our discussion on a nursing home scenario. Based on an initial feasibility study with nurses supporting Dementia and Alzheimer's patients at the Mainkofen Hospital in Germany, we analysed the nurses' daily routines and divided these into four generic activity patterns:

– Activity Type I: perform $action_a$, e.g., prepare injection.
– Activity Type II: perform $action_a$ with $object_o$, e.g., sterilising a scissor.
– Activity Type III: perform $action_a$ to $patient_p$, e.g., change dressing of patient one.
– Activity Type IV: perform $action_a$ with $object_o$ to $patient_p$, e.g., measure blood sugar level of $patient_p$ with a glucose meter.

Each activity is composed of an *action* and optionally an *object* (e.g. a blood pressure monitor) or a *patient*. The study results suggested that in most cases actions only involve a single object and patient. Further analysis of these activity types and discussion guided us to identify six distinct information types:

1. *Identity and Relationship*: This category of information describes the identity of a patient, medical equipment, etc. and their relationship with each other in the context of an activity. This type of information helps nurses to make informed decision regarding which equipment to use with which patient.
2. *Status*: This category of information reflects an individual's or an object's status, e.g., the operational status of an equipment (e.g., faulty, working).
3. *Instructions*: This information type provides guidelines to perform medical routines with or without specific medical equipment.

4. *Confirmation*: Feedback about the successful completion of a medical routine with or without specific medical equipment.
5. *Explanation*: This category of information provides explanations to address exceptional situations, e.g., when devices are malfunctioning.
6. *Trends*: Temporal trail or history of an equipment's status or patient's medication record.

In the next subsection, we look at how these information types can be encoded into situated glyphs.

2.2 How: Representation Density

Representation Density specifies how a glyph can be designed to present real world information using patterns, texts or pictures, in other words, it answers the "How" aspect of situated glyphs. A glyph can be abstract or very concrete depending on the situation at hand.

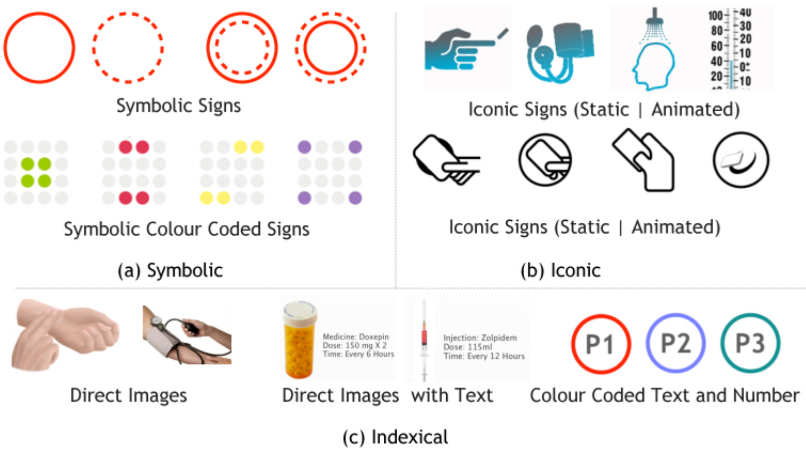

Fig. 2. Semiotics Signs: Symbolic, Iconic and Indexical

We observe that glyphs can be expressed in the language of semiotics, the branch of philosophy that deals with signs and their meanings. A semiotic sign is made up of three elements: *signified*, *signifier*, and *sense* [4]. *Signifier* signifies a *signified* (physical object) through *signs* to

Information Affinity \ Representation Density	Symbolic	Iconic	Indexical
Identity & Relationship	Yes (With Colour)	Yes (With Multiple Icons)	Yes (With Colour, Text and Number)
Status	Yes (With Colour)	Yes	Yes
Instruction	No	Yes	Yes
Confirmation	Yes (With Colour Code)	Yes	Yes
Explanation	No	No	Yes
Trends	No	Yes (With Animation)	Yes

Fig. 3. Design Space of Information Affinity and Representation Density

give a sense to an observer. Semiotic signs can be Symbolic, Iconic or Indexical. Symbolic signs are completely arbitrary and abstract and need implicit domain knowledge for interpretation as shown in Fig. 2(a). Iconic signs have an intermediate degree of transparency and provide a metaphoric representation as shown in Fig. 2(b)[1]. Indexical signs are much more direct and reflect the signified object with high fidelity as shown in Fig. 2(c).

We are interested in portraying different information types into situated glyphs using semiotic signs. To this end, Fig. 3 plots various areas of representation among our identified information affinity and semiotic signs. Whilst it may be interesting to explore symbolic or iconic representations for artistic purposes especially consulting the contemporary literature on persuasive ambient displays aimed towards behaviour shaping [6, 10], looking at the design space it is clear that indexical signs are best suited for our purpose of designing situated glyphs as shown in Fig. 3. This is mainly due to the limitation of symbolic and iconic signs' capabilities in expressing instructions and explanations articulately. We are currently investigating different glyph designs using indexical signs. In this paper, we present one of the designs as an example to ground our discussion so far. Fig. 4 depicts the design of a simple glyph that utilizes colour, text and number to represent the different information types we have discussed earlier. It has a rectangular shape with multiple properties in accordance to the activity pattern introduced earlier. These properties are:

– The first property is the *colour* which is used to represent relationships : every individual and object is assigned a colour; an individual can perform an action with an object (optionally to another individual) only if their colour matches.

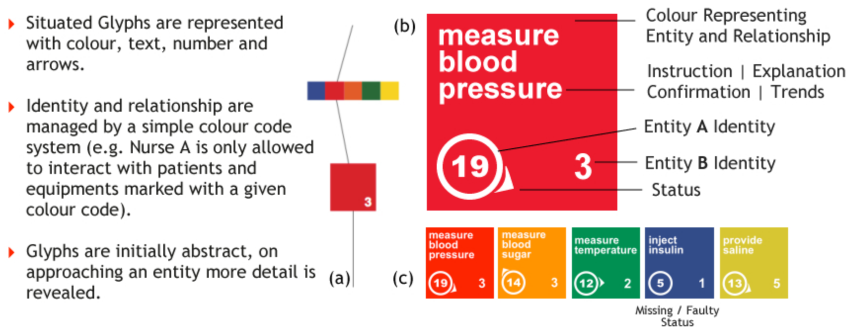

Fig. 4. An Illustrative Design of a Situated Glyph

– The second property is the *identity* which is represented by a number (lower left and lower right). Two sub properties of this identity property are a circle and a pointing arrow. The circle (lower left) represents the active component of an action (e.g., an object or a patient) as described earlier. The presence of a pointing arrow (compass metaphor) represents the status of the component (working or faulty, available or not etc) and its location direction.

[1] Some of these signs are collected from http://www.elasticspace.com/2005/11/graphic-language-for-touch.

– The final property is the textual description of the *action* in the form of instruction, explanation, confirmation or trends. In addition, this property is *animated* to highlight the urgency of an operation and to slide through the historical stages.

Consequently, the glyph shown in Fig. 4 (b) corresponds to a "red" coded nurse's activity of measuring blood pressure with a "red" coded patient numbered "3", using a "red" coded blood monitoring device numbered "19" which is available in the south-east direction and working fine. This glyph design is adaptive and dynamically changes its content depending on the activity at hand and the context of the activity, i.e., glyphs are initially abstract, on approaching an individual or an object more detail is revealed as shown in Fig. 4 (a).

2.3 Where: Spatial Distribution

Spatial Distribution describes the distribution granularity and placement alternatives of situated glyphs and corresponds to the "Where" aspect of the design space. One interesting point of discussion is defining the optimum number of glyphs distributed across the environment. This placement granularity reveals the design trade-off between information capacity and fragmented attention. By increasing the number of glyphs it is possible to present more fine-grained information[11]. Additionally, information can then be dispersed across these glyphs in a more situated fashion, i.e., a glyph embedded in an object shows only information about that object instead of showing about the activity as a whole. However, the caveat of increasing the number of glyphs is that it introduces fragmentation of attention due to the demanding context switches which consequently increase the cognitive load of the individuals involved in the activity.

Taking these distribution choices into account, we envisage that there are multiple possibilities for the placement of the glyphs. Delving into the "Situative Space Model" introduced by Pederson [12], we can logically distribute the glyphs into *manipulable space* and *observable space*. A third alternative is the physical embodiment of a glyph onto an entity. Accordingly we identify three design alternatives for placement of glyphs:

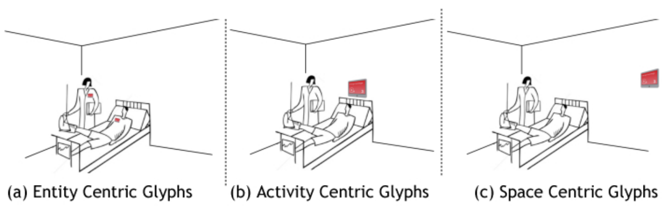

Fig. 5. Placement Possibilities for Situated Glyphs

1. *Entity Centric:* A glyph is embodied in every entity as shown in Fig. 5(a). For individuals these glyphs come in a wearable form whereas for physical objects, glyphs are embedded in them.

2. *Activity Centric:* A glyph is placed at the location of the activity climax or in the manipulable space as shown in Fig. 5(b). As an example, for an activity involving a patient and a blood pressure monitor, the glyph can be placed on the patient's bed assuming this activity will be conducted while the patient is in bed.
3. *Space Centric:* A glyph is placed in the observable space and is shared across multiple activities and entities as shown in Fig. 5(c). An example of this kind of glanceable space is the wall between two patients' beds.

Entity centric glyphs represent the extreme end of the spatial spectrum, even though they provide the finest detail of information, they introduce maximum fragmentation of attention in comparison to activity centric and space centric glyphs. In addition, entity centric glyphs require less information updates and adaptation dues to their situated nature compared to the other two alternatives.

2.4 When: Temporal Distribution

Temporal Distribution specifies the timing of information provision that a situated glyph provides and refers to the "When" aspect of the design space. This timing is directly related to the information affinity, i.e., different information requires different timing for presentation. Analysing the physical activity, we observe that there are three phases of any activity - pre-execution phase (before), execution phase (during), and post execution or evaluation phase (after).

Delving into Suchman's situated theory of action [13] and considering our identified information affinity, we have devised an information-timing matrix for situated glyphs in the context of health care domain. This is depicted in Fig. 6. The figure exposes the timing demand of each information type. As an example consider *relationship* information. It is essential for a nurse to know before performing a medical routine with an equipment that this is the right equipment for the patient in context. Furthermore, the relationship information should be maintained during the execution to ensure interaction consistency, and finally also be present after execution to receive the confirmation that the routine was successfully recorded for that patient. On the contrary, *status* information is only needed in the pre-execution phase to ensure that an equipment or an individual (e.g., a patient) is available. A further example is the instruction information which is only needed before and during an activity to support the action but not once the activity is completed.

	Temporal Distribution		
Information Affinity	Before	During	After
Relationship	Yes	Yes	Yes
Status	Yes	-	-
Instruction	Yes	Yes	-
Confirmation	-	-	Yes
Explanation	-	Yes	-
Trends	Yes	-	-

Fig. 6. Information Affinity - Temporal Distribution Matrix

3 Discussion

In the previous section, we have discussed the design space for situated and activity-aware glyphs to support dynamic work environments. Technically, such situated and activity-aware glyphs can be realised as a distributed display network. In our current prototype we have designed situated glyphs with a custom designed micro display network using Jennic JN5139 micro controllers with OLED-160-G1 displays with a resolution of 160x128 pixels at 65k colors, and running Contiki Operating System providing a TCP/IP suite on top of ZigBee wireless standard (Fig 7).

Fig. 7. Current Prototype with a Physical Size of 51mmx30mm

We feel our analysis opens up several promising directions for future research. Firstly, one caveat of our current design space is that we have not considered the interactivity aspect of situated glyphs. As it is unclear at this point that what kind of interactivity is suitable, we would like to address this in the immediate avenue of our future work. Secondly, we consider situated glyphs can be designed in many ways. In this work we have borrowed concepts from semiotics, but we feel this is an open space. In fact, many prevailing information visualisation techniques can be explored to design situated glyphs in the context of pervasive computing. Next, since situated glyphs convey what activities can be performed in a given space, at a given time, with the devices and objects at hand, they can be used to improve the intelligibility [7] of the underlying context-aware system by exposing the internal behaviour through articulated explanation and adaptive feedback. Further exploration on this area would contribute in shaping users' understanding towards such system. Finally, the analysis of spatial distribution granularity naturally prompts us to look further into the question of "how much is too much?". This is particularly important to understand the relationship between information overload and granularity of situated glyphs. As previous studies have concluded that individuals become selective and ignore large amounts of information when information supply exceeds their information processing capacity [8, 9] and this also contributes to the fragmentation of attention thus increasing the cognitive load. Unless we perform in-situ real world studies in different domains addressing different situations, it won't be possible for us to determine or approximate the upper or lower bound of the placement granularity of situated glyphs. We see opportunities for field studies that can help us in gaining further insights towards the design of situated glyphs.

References

1. Heyer, C.: Investigations of Ubicomp in the Oil and Gas Industry. In: Proc. of Ubicomp 2010, pp. 61–64 (2010)
2. Bardram, J.E.: A novel approach for creating activity-aware applications in a hospital environment. In: Gross, T., Gulliksen, J., Kotzé, P., Oestreicher, L., Palanque, P., Prates, R.O., Winckler, M. (eds.) INTERACT 2009. LNCS, vol. 5727, pp. 731–744. Springer, Heidelberg (2009)

3. Bardram, J.E., Hansen, T.R., Mogensen, M., Søgaard, M.: Experiences from real-world deployment of context-aware technologies in a hospital environment. In: Dourish, P., Friday, A. (eds.) UbiComp 2006. LNCS, vol. 4206, pp. 369–386. Springer, Heidelberg (2006)
4. Ogden, C., Richards, I.: The Meaning of Meaning. Routledge and Kegan, London, England (1923)
5. Chernoff, H.: The Use of Faces to Represent Points in k- Dimensional Space Geographically. Journal of the American Statistical Association 68, 361–368 (1973)
6. Jafarinaimi, N., Forlizzi, J., Hurst, A., Zimmerman, J.: Breakway: An ambient display designed to change human behavior. In: Proc. of CHI 2005 (2005)
7. Bellotti, V., Edwards, K.: Intelligibility and accountability: human considerations in context-aware systems. Hum.-Comput. Interact. 16(2), 193–212 (2001)
8. Eppler, M.J., Mengis, J.: The concept of information overload: A review of literature from organization science, accounting, marketing, mis, and related disciplines. The Information Society 20, 325–344 (2004)
9. Müller, J., Wilmsmann, D., Exeler, J., Buzeck, M., Schmidt, A., Jay, T., Krüger, A.: Display blindness: The effect of expectations on attention towards digital signage. In: Tokuda, H., Beigl, M., Friday, A., Brush, A.J.B., Tobe, Y. (eds.) Pervasive 2009. LNCS, vol. 5538, pp. 1–8. Springer, Heidelberg (2009)
10. Hallnas, L., Redstrom, J.: Slow technology - designing for reflection. Personal and Ubiqutious Computing 5(3) (2001)
11. Pousman, Z., Stasko, J. : A taxonomy of ambient information systems: four patterns of design. In: Proc. of AVI 2006 (2006)
12. Pederson, T.: From Conceptual Links to Causal Relations Physical-Virtual Artefacts in Mixed-Reality Space. PhD Thesis, Dept. of Computing Science, Ume University, ISBN 91-7305-556-5
13. Suchman, L.A.: Plans and Situated Actions: the problem of human machine communication. Cambridge University Press, Cambridge (1987)
14. Mann, T.: Visualization of WWW-Search Results. In. Proc. of DEXA Workshop (1999)
15. Ware, C.: Information Visualization Perception for Design. Morgan Kaufmann Publishers, San Francisco (2000)
16. Chuah, M., Eick, S.G.: Information rich glyphs for software management. IEEE Computer Graphics and Applications, 2-7 (July-August 1998)