Supporting indoor evacuation through landmarks on mobile displays

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Summary We present an attempt to establish the role of a PDA during emergency evacuation from indoor settings. We attempt to present a methodology for establishing a framework of information visualization for specific needs; evacuation conditions in this paper. A general classification of landmarks is presented first. This is followed by an attempt to give a holistic range of visualization possibilities. A user test was conducted to corroborate some of the postulates we made regarding the ideal depiction for each class of landmark. The setup and results of this test are described. Our goal is to present an approach that we used for evacuation conditions in indoor settings specifically, but one we believe can be translated for other contexts as well.

Introduction

Advances in technology have increased the effectiveness of the mobile phone as a context-aware agent, either via activity recognition (*Kray* 2004) or by location sensing and positioning (*GPS, Gallileo, Cricket*, etc.). What this presents is an opportunity to transform the mobile phone from just a handy telephone, to a handy source of ubiquitous, *pragmatic* information. Projects have been done to harness this potential of the mobile phone for tourism where this could prove invaluable as value addition to an enriching experience. One other possibility is disaster management where the presence of directed, unambiguous and uncluttered information could be invaluable for both evacuees and rescue personnel. Research has been done to improve the interoperability of relief services, improve the automatic generation of escape routes (*Pu & Zlatanova*, *Zlatanova et al*. 2005) and so on. What we did not come across was an attempt towards the user centered visualization of evacuation information, which we feel is just as important as the system architecture as it is the first "frontier" during the actual usage of the system. To this end, we present first a general approach to geographic information visualization on the mobile screen and then postulate and test a framework for evacuation purposes.

Briefly, when evacuating a building, the chief source of panic is confusion - that stems from a cognitive overload - too much information to deal with but not enough pragmatic information (*Chao et al* 2001). In the case of people new to the building, the main problem is a lack of orientation - where they are with repect to the exit and the building (*Boer et al* 2004). A lot of confusion can be eliminated by just, firstly, telling the person where he is - in spatial language he can quickly grasp, and then let him know how to leave. Also helpful, we believe, might be the knowledge of where exactly the source of danger is and if possible, alternate escape routes as well.

Parameters for effective evacuation maps

Based on literature on map and visual communication design (*Tufte* 1990, 1997, *Kosslyn* 1989, *Keates* 1996, *Lloyd* 2000), we chose the following points as parameters for effective maps for evacuation purposes. Based on these, we made some hypotheses as explained in a later section and these were also the key factors which we finally tested out.
1) Completeness: The degree to which the map is adequate for the evacuee to make his way out. The aim in the previous section was to get a complete representation of the exit route.
2) Flashbulb time: The time it might take for the evacuee to scan the map and internalize it.
3) Visual clutter / perceptual quality: The more visual clutter (*Philips and Noyes* 1982) there is, the more time it takes for the evacuee to understand the message. Visual clutter implies a high flashbulb time but the lack of it might not mean that a map is internalized quickly. This is why we list the flashbulb time as a seperate point here.
4) Symbol clarity: The degree to which symbols used are understandable without putting a legend into use. A safe hypothesis may be that greater the degree of iconicity (*Gattis* 2003) of the symbol, more clear it will be. This was one of the key goals of our test.
5) Consistency: Whether the same scheme of symbols is used throughout a series of signages. This is because similarity helps in buiding mental links between different signages and the message of each sign has to be deciphered if the evacuee is to get out of the building safely.

Visualization of evacuation information

Our main aim in this section is to look at the various facets of envisioning evacuation information on small screens. The design of efficient wayfinding aids depends on a good understanding of the wayfinding process itself (*Passini* 1992). A basic approach to wayfinding processes is given by Downs and Stea (1977), who differentiate the following four sub-tasks:

1. Orientation, i.e. determining one's position in an environment,
2. Choosing the route, i.e. planning one's route to the destination,
3. Keeping on the right track,
4. Discovering the destination.

With these points as our goals, we subdivide this topic of visualization into the following topics:

- Why use a map for communicating evacuation information.
- What are landmarks? What are their chief characteristics?
- How can landmarks be classified?
- How to choose landmarks for indoor settings.
- How can each landmark be visualized.
- How can spatial relationships be depicted on small screens.
- Evolving frames of reference and the small screen
- Options to be presented to the evacuee.
- The evacuation context.

We will now look at each of these topics in turn and this should give us a fair understanding of information visualization for evacuation conditions.

Classifying landmarks

We classify landmarks from various points of view here to get a better understanding of them and to more effectively choose a landmark when necessary. The intention here is to get as comprehensive a taxonomy as possible and to list the attributes of each "type" of landmark. The next step would be to postulate a mode of visualization for each type of landmark. The hopeful result is that

- By quantifying the attributes of each type of landmark, we can judge the usefulness of any object in an environment as a landmark and
- If we create a set of pairings of attributes and visualizations for types of landmarks then it is possible for a PDA/server to automatically generate the most pragmatic visualization for a landmark *which might not always remain the same*.

For example, a lot of objects and information have to be shown on screen and perhaps, the next landmark at the next decision point from where the person is standing may be shown as a sign or just text initially, but may need to be shown in visual detail as he approaches it. This could also be feedback about the distance of the evacuee from that particular node.

We have three basic ways of looking at landmarks, from *structural*, *semantic* (*Raubal and Winter* 2002) or *physical* points of view.

1) *Structural classification*: We classify landmarks, structurally, based on their location with respect to the evacuee or with respect to the whole environment (which may be the whole floor of the building or the building itself). With respect to the evacuee, we can classify landmarks as:

- *Global vs local*
- *On-route vs off-route*

2) *Physical classification*: We can classify a landmark either by the nature of the physical object or the characteristic which sets that object apart as a landmark. Objects in the evacuation environment may be earmarked as landmarks based in the following two broad ways:

- *Visual vs functional*:
- *Rigid vs movable*:

3) *Semantic classification*: We can classify landmarks based on how they are considered by evacuees and how evacuees interact with them in normal, non-evacuation conditions. We can classify landmarks as:

- *Orientation vs reinforcement*
- *Denotative vs connotative visual landmarks*

The classification that will be discussed in the full paper may be represented as shown in fig 1.

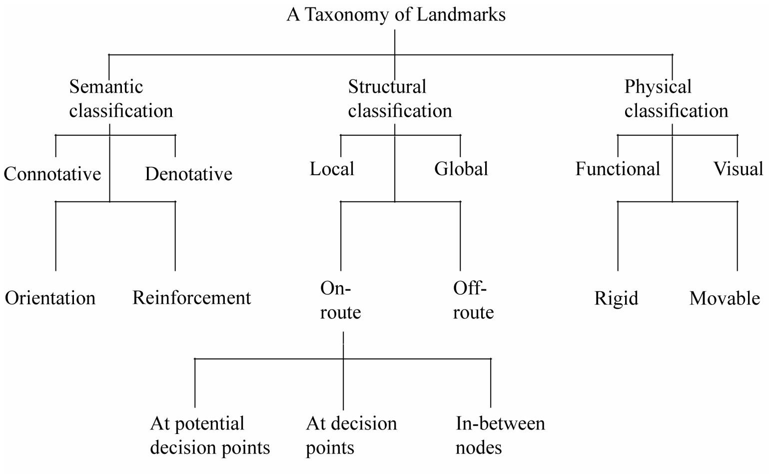

Fig. 1. The presented classification of landmarks

Picking attributes for the types of landmarks

The next step is to list the major attributes of each type of landmark, so that any object can be classified as one of these "types" based on the attributes it does (or does not) possess.

- *Visual landmarks*: The key features for a visual landmark are visibility and differentiation (uniqueness) (*Dickinson et al* 2006). *Raubal and Winter* 2002, *Raubal, Winter and Nothegger* 2005 describre relevant factors.
- *Functional landmarks*: (the relevant attributes will be described in the full paper)
- *Rigid vs movable*: Intuitively, a rigid object may be more preferable to a highly movable object as it might not get moved around in an evacuation condition.
- *Global vs local:* As we will later see, the main reason this bifercation matters is the level of detail in which to represent the object. The reason is explained in the full paper.
- *On or off-route*: This is an objective measure and it depends only on the object's location and the computed escape route. All the subdivisions of the on-route landmarks are the same way.
- *Connotative vs denotative / semantic "value"*: This is a more subjective measure than what we have seen so far. Some of the attributes of connotative landmarks might be:
  - *Cultural and Historical Importance* (*Raubal and Winter* 2002)*:*
  - *Symbolic value*: Some entities have become attached with symbols. For instance, McDonalds is best represented by its logo (*Betke et al* 2005).
- *Orientation vs reinforcement landmarks.*

The different classifications presented here are not exclusive. This particularly comes into play when we try to quantify each variable. Some postulates/statements we can intuitively make are:

- Off route landmarks can mainly help in the (re)orientation of the evacuee
- Off-route landmarks should be treated as global landmarks
- Denotative landmarks are highly visual landmarks
- Global landmarks may be for orientation and local landmarks for re-inforcement
- Local landmarks are best used in between nodes.
- Functional landmarks are better for people familiar to their settings [tested]
- Visual landmarks are better for people new to their settings [tested]

These statements are important for the following reasons:

- Each major classification will have one visualization "paradigm" that we propose in a later section and test with a first user study
- Each object will have to be compared with the attribute list and classified.

Such cross-references might help in getting a more comprehensive solution. Some attributes can be directly quantified beforehand. For instance, the facade area of an elevator can be directly calculated. Some attributes however can only be judged empirically against a scale, cultural importance for example. Some other attributes can probably be judged objectively. For instance, social frequency "may" be measured, by probably sensing PDA signals, much like situated diplays in Krüger (2003). We will now look at how each "class" of landmarks can be visualized.

Visualization of individual landmarks

With respect to depicting individual landmarks, the two issues that need to be looked at are: "which mode of depiction might suit our purposes best" and "what traits of the object to depict when necessary". The latter might be better understood with the statement "what traits of an elevator contribute most to its elevatorness, that are most associated with it and would be most quickly associated with it during recall".

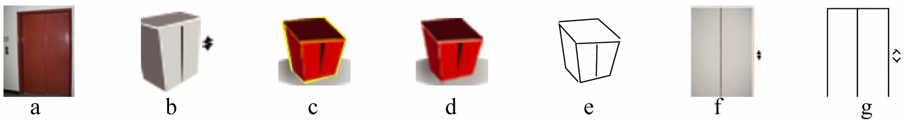

Fig. 2. Some ways of representing a major landmark on a mobile screen. (a) taken from http://www.it.stlawu.edu

Some of the main ways of representing individual major landmarks are as shown above, in decreasing detail from left to right. We base this discussion again on the two theories presented in an earlier section which say that we remember objects based either from a snapshot of memory or from their structural properties. Silhouettes as part of the structure-based object perception play an important role in preceiving the object since many objects (take the statue of liberty for instance), have definitive silhouettes and are easy to recognize. Line drawings are considered equal to silhouettes and line drawings are particularly effective when rapid responses have to be made. This follows from the structural theory. However, when all the information of an object that needs to be presented in order to ensure recognition, cannot be presented (maybe due to space constraints like in a mobile screen), then, line-based drawings are the least effective form of representation. A study (*Elias et al* 2006) conducted to test the speed of perception from different representation types used four main types of representation: Photographic, shaded drawing, line drawing and cartoon. It was found that cartoons were most easily perceived and line drawings were least easily perceived.

What we postulate, building on this study is that people who are very much familiar with an object tend to remember an abstracted version of it i.e. remember it structurally. People who have only seen an object once, either remember a snapshot of the object, remember it by its name or function, or dont remember it at all. Based on this theory here, we infer that a cartoon like depiction of the global landmark, with its chief defining characteristics exaggerated (part d of figure 1 for example) is probably the best for the instant recognition of the object. Adding an outline will only accent the loandmark and maybe draw attention to it as well thus making part c of figure 1 the ideal way to represent an elevator on a mobile screen for evacuation purposes.

Based on these theories and tests, we can formulate a "matrix" of visualization possibilities as shown in figure 3. In the lower part of the figure, we summarize the possible inter-relationships of the various classes as discussed in an earlier section. A cartoon figure was most easily perceived in Elias et al (2006). For this reason, by augmenting the cartoon with the function of the object, we can conclude that (3) would be fitting functional depiction of a sliding door. Visual landmarks need to be depicted, we infer, as quasi-realistically as possible as their recognition / recall hinges on their visual features. But photographs of such a small size (75x75 pixels in this case), may not be understood very quickly. For this reason, we infer, a depiction such as (5) fulfills the required criterion for a visual landmark. This matrix is as depicted in figure 3.

Connotative landmarks, however, rely heavily on their appearence. Also, we choose for connotative landmarks, objects with some significance/importance and it's more probable that people would be familiar with them, if not their location in the building in all cases. So, showing the landmark in its physical setting, contrasted against the surroundings by its visual attributes would, we hypothesize, be an effective depiction.
The case of local landmarks then arises. If a detailed isometric representation of an object is given, it will only be an advantage when the user can perceive it from the same angle (*Davis* 1989). If the view shown differs from the view presented, it may only be more problematic for the evacuee. This is what is likely to happen if 3D views of local landmarks are presented. The possibility that we have a host of depictions for each landmark, each from a different point of view can be considered here. However, such a case will warrant a very precise positioning technique. For this reason, we propose the frontal views (2, 4) for local landmarks.

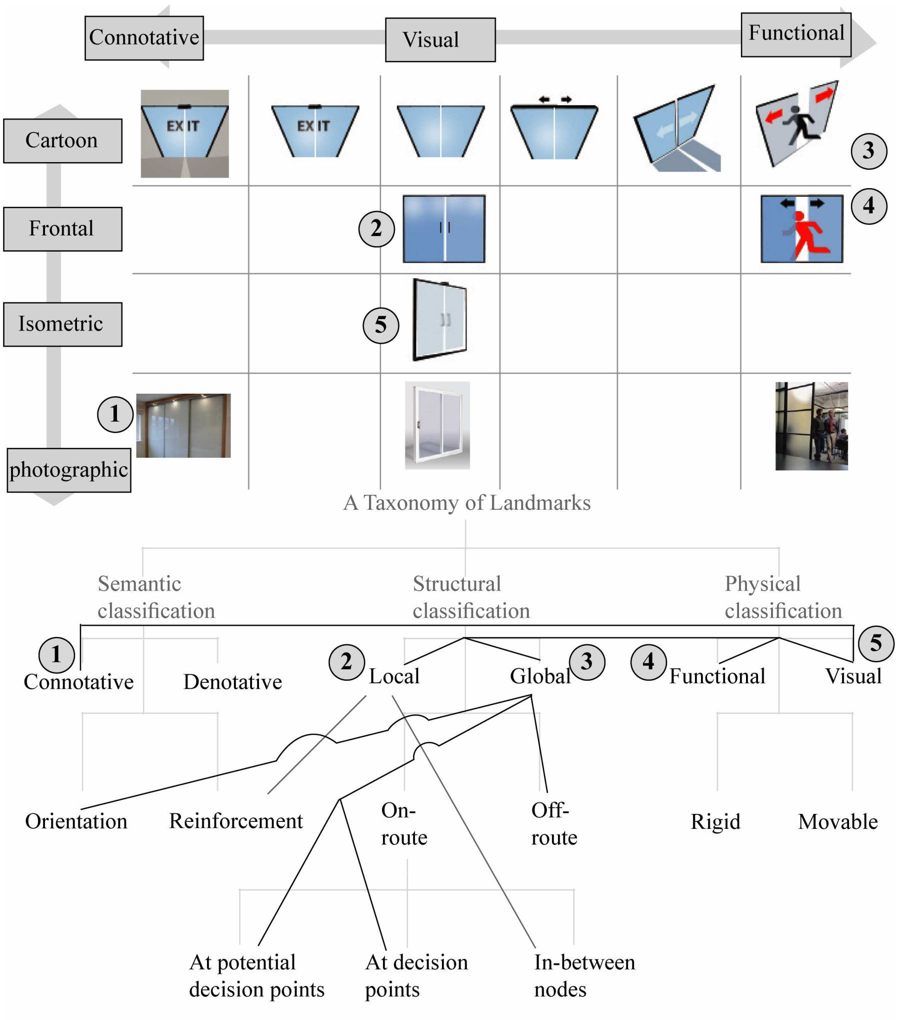

Fig. 3: Different depictions for the different classes of landmarks.

Representing spatial relations on the mobile screen

The main relations we have to portray on the small screen are between the landmarks themselves and where the user is located with respect to them. The key relation is the distance of one landmark to another. Generally the practice is to use on-screen distance between the landmarks proportional to the real world maps (*Rystedt* 2001) The problem arises when we are faced with large distances that need to be shown on the screen. Scaling down all the routes uniformly will leave us with little place to represent local landmarks as they come along. It is very helpful, we hypothesize, to show the complete route to the exit and not just to the next "checkpoint" or major choice point. This postulate we corroborate in a later section. These are the problems that crop up when we try to "scale down" the escape route to fit on the map.

To solve this problem, some of the techniques (*Noik* 1994) we can use are

1) Scaling down the landmarks to simulate perspective.
2) Scaling down the "route" to simulate perspective.
3) Using colour to simulate distance

The perspective or lack of perspective can help in creating hierarchy as required. Given in figure 2.6 are some examples of these principles in practice. 'a' shows how focus is created by breaking perspective of the route. 'b' does not break this perspective. 'c' shows the perspective of the route maintained but the view of the landmark breaks the "rules" of the layout, which may possibly make this a confusing layout. 'd' shows the major methods put to use. Size of the landmarks is also subject to perspective as is the route. A slight "altitude" is given to ensure focus, while level of detail is uniformly maintained. e uses level of detail in favour of the “altitude” effect. Text is used to augment the landmaks in most of the cases but in ‘e’, textual instructions are also given initially.

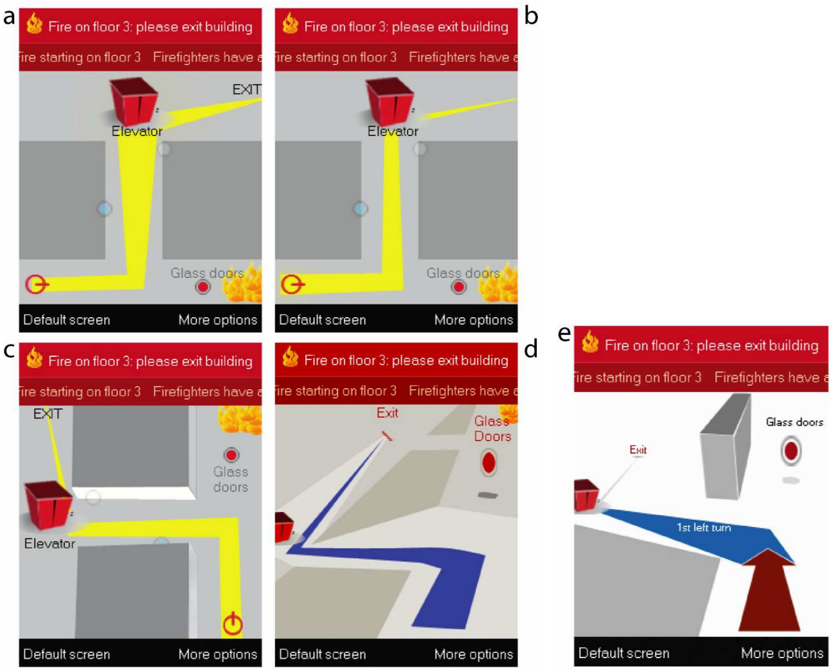

Fig. 4: The various possibilities as explained above.

Schematisation on the small screen

Schemetisation here refers to reduction of information content, from a rich physical world to sketchy content (*Klippel et al* 2005). In the scenario of emergence evacuation we also have a very low threshold for cognitive overload. The evacuee has to convert the information he sees on the mobile screen to the real world and the more “unnecessary” information he sees, we believe, the tougher he finds this translation. We refer back to the five examples presented in figure 4. Schemetisation in the first four examples (a to d) varied through different levels but essentially remained the same throughout. In the fifth example ‘e’, we see how a change of schemetisation can effectively act as both a local landmark if well implemented and also creates focus on screen due to the elaboration in that part of the screen. We may or may not subject the “flattened” part i.e. the schemetised part of the image to perspective, only detailed user testing will determine which is more beneficial.

Evaluation by User study

With a framework postulated as shown in a earlier section, we set out to test some of the postulates we earlier. The aim of the test was to simulate evacuation conditions and to see how effective the different modes of visualization were in guiding the evacuee out. Some of the main issues that we wanted to test out were:

- How much of the escape route be shown? (magnification)
- What role does text play?
- How much infomation of the “floor” is appropriate?
- What is the “ideal” depiction for each type of landmark?

The test was a walkthrough through a “post disaster” environment. We chose a fire evacuation condition. The layout of the floor was unconvential and a visibility was quite low due to the smoke simulated. We also wanted to simulate the panic associated with the evacuation condition, to some extent. We attempted that by creating a “jerky” walkthrough where the question of “how to control my movement” conflicted with “where do I go” to increase the cognitive load on the evacuee. People’s spatial abilities depend mainly on perceptual capabilities, fundamental information processing capabilities, previously acquired knowledge and motor capabilities (*Allen* 1999, *Garling* 1983). The smoke filled conditions and jerky movement coupled with the strange environment helped increase the subjects’ reliance on the maps. The smoke filled conditions greatly lowered visibility. We then provided the evacuees with “mobile maps” which they could check as they progressed.

Fig. 5: Some screenshots of the test.

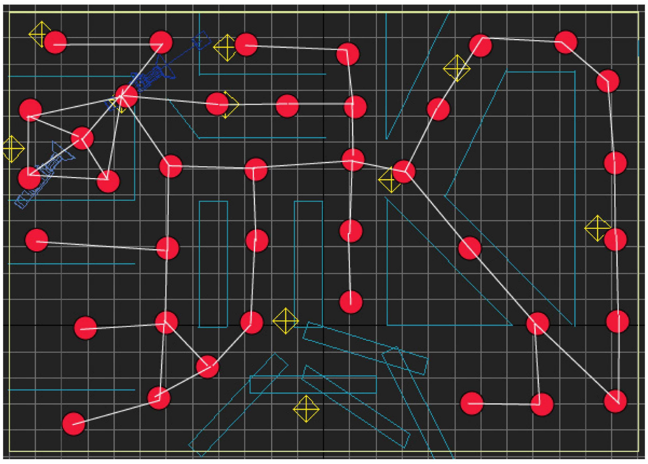

Fig. 6: The layout of the test possible locations the evacuee could move through.

To guide the evacuee around, we put “landmarks” like a fire extinguisher, a painting, a sculpture and an elevator in the layout of the floor. These landmarks from highly visual like the sculpture and highly functional like the elevator. We used a painting of Lord Buddha as a connotative landmark. We then created five different versions of the test, each with a different depiction of each type of landmark. The parameters used to judge performance of the test subjects were the time taken to succesfully find the exit and number of “errors” made. An error was classified as a step taken outside the designated escape route.
Many of the postulates we made for the “ideal” landmarks were corroborated. Some were not. We determined the following from the results of the tests as well as the comments we solicited from the subjects after the test.

- The cartoon depiction used for the visual landmark proved less effective when compared to the quasi- realistic isometric depiction.
- A clear front view of the connotative landmark was preferred.
- An abstracted depiction of the functional landmark, highlighting its function was preferred.
- The functional landmark (an elevator in this case) was the most helpful landmark, according to the subjects. The problem arose with its lack of “visual differentiability”. A highly visual landmark worked great for orientation.
- Too much text proved detrimental and “unnerved” the user form using the map.
- Text might be best used by always having it for global landmarks but only “switching it on” for local landmarks when the evacuee is near them.
- Just text and a dot seemed to work well enough for local landmarks.
- Showing the layout of the whole floor proved detrimental (as in the case of group 5).

The findings of this study can be represented as in figure 8. The time subjects took in deciding if they were at the right place and where to go next, at each landmark, was gauged by observing them take the test and also by their comments. The number and location of errors made enabled us to judge the "effectiveness" of each landmark as judged by the width of each bar in figure 8.

More detailed results and findings of the user study will be presented in the full paper.

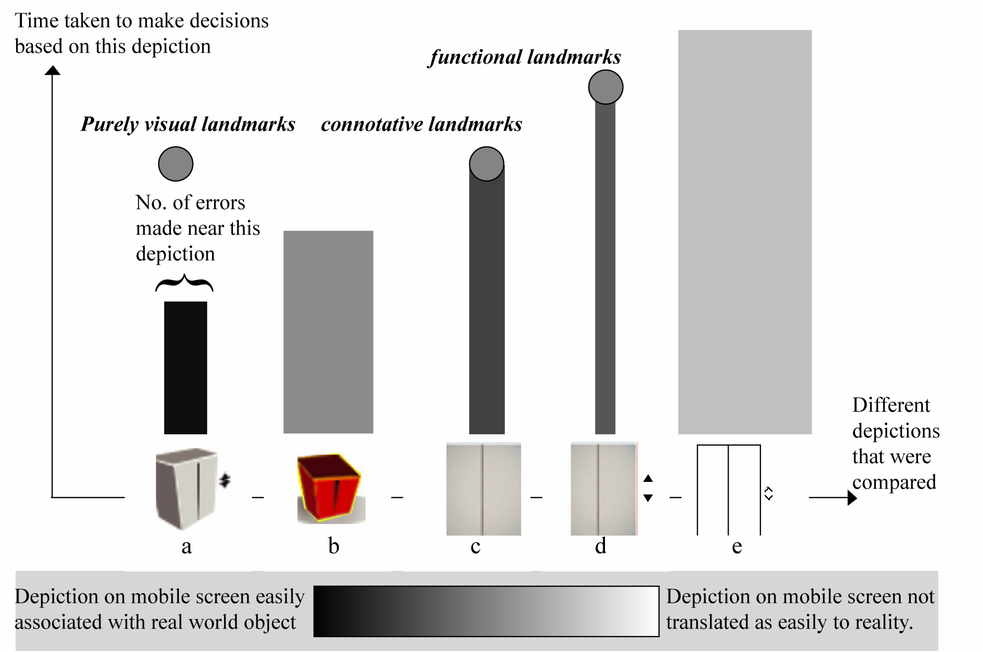

Fig. 8 A comparision of the different depictions used in the user test

Summary and Outlook

We presented an overview of the different methods of interacting with a PDA today. Then a general framework was laid down on the various facets involved in visualizing information on the mobile screen. The test here was successful in simulating evacuation conditions, to an extent. The next step would be to implement some of the views and ideas presented and test these possibilities in a physical test and solidify the inferences drawn here.

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