Guides, locals, chaperones, buddies and captains: managing trust through interaction paradigms

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ABSTRACT
A key problem in context-aware mobile computing is one of reconciling or mapping the physical and the virtual planes during interaction. This paper describes six possible characteristics of this 'mapping problem' to understand and describe possible *interaction paradigms* for use when designing context-aware mobile guides. We draw from two evaluations of two mobile guides: the GUIDE project from the University of Lancaster, England and the Trammate project from the University of Melbourne, Australia. The six characteristics of mapping problems described here are *determinism*, *transparency*, *accuracy*, *indexicality*, *predictability of content* and *predictability of behaviour*. Through these two cases we continue to discuss the consequences of failure to design for effective mappings: namely a failure to match users' expectations and a consequential loss of trust. We then describe five possible interaction paradigms for context-aware mobile guides (*guide*, *local*, *chaperone*, *buddy*, *captain*), based on the six characteristics posited in the paper. We suggest that these paradigms can be used to provide assistance to designers building context-aware mobile guides for trust.

Keywords
Mobile guides, context-aware mobile systems, mapping, interaction paradigms, trust, design support

1. INTRODUCTION
Characterising possible interaction paradigms has been important in the history of interaction design. Describing systems as having a command line or GUI interface, for example, has enabled interaction designers to understand user expectations better. These paradigms also assist users in knowing what to expect when interacting with such computing systems. Generic categories have also been utilized in fields such as Information Systems, to help make sense of types of systems for example, facilitating the discussion of possible solutions to problems across different contexts. Such terms can also be regarded as part of a toolbox that assists with the design of systems.

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Mobile guides are defined as "systems that guide mobile users by providing local and location-based services, such as navigation support and tourism information" [22:1]. Kray and Baus [16], review and compare nine different mobile guides from 1996 to 2003. They extract five dimensions characterising guides: *basic features*, such as the positioning technology deployed within the system; *situational factors*, including the user's ability to select content; *adaptation capabilities*, such as the system's adaptability to user position; *interface and user interaction*, the system's support for multiple modalities and natural language, for example; and *architecture* or the network and system technology used to develop the guide. Here, we focus on *situational factors*, *adaptation capabilities* and *interface and user interaction issues*, with a view to providing support for design teams developing 'intelligent' context-aware mobile guides. We aim to enrich the understanding of *interaction paradigms* for these guides.

Our suggestion is that digital guides often borrow design features from existing sources of information in use but rarely consider the impact on the user's trust of the system. Three such sources are *guidebooks*, *tour guides* and *tourist information centres*. A *guidebook* is "a book of interest about a place, designed for the use of visitors or tourists" [17]. A *tourist guide* is "a person who guides visitors in the language of their choice and interprets the cultural and national heritage of an area, which person normally possesses an area-specific qualification" [5]. A *tourist information centre* is "…an office, usually run by a tourist board or local authority, providing information about the locality to visitors" [5]. Of these three, clearly the guidebook is the least 'intelligent' with both the tourist guide and the tourist information centre having some 'intelligence', to support a dialog with the visitor in order to react to queries made by the visitor based on an human understanding of their abilities, for example.

Digital guidebooks (e.g. *CyberGuide*, [1]), perhaps inspired by the design of tourist guidebooks, operate much like information repositories with limited 'intelligence', indexing and limited opportunities to construct complex queries. Thus the search space can be large and require some level of user skill to navigate. This type of mobile guide focuses on providing basic features to the user, has limited accommodation for situational factors (e.g. context), has limited adaptation capabilities and tends to devolve control to the user.

Digital tourist guides organise information and interaction according to specific rules and constraints with some flexibility in navigation. For example, the Peach system [30] organises information (i.e. cinematic narrations and animations describing frescoes in a museum in Trento) in a way that is highly linear but extremely expressive with regard to the subject matter. However, it is important to note that digital tourist guides may also be designed to appear 'intelligent' and take control away from the user (as with a traditional tourist guide) as illustrated by the 'on-tour' mode supported by the GUIDE system [8].

Digital tourist information systems (e.g. DeepMap, [15]), reflecting physical tourist information centres, operate like decision-support systems, providing information to assist with problem-solving and providing indexed responses to complex querying. Digital tourist information systems tend to be democratic with control and again can exhibit some level of intelligence, e.g. by the utilization of user modeling techniques.

Characterization of interaction paradigms has been useful when addressing particular design problems for particular users completing particular work in particular contexts. Form-based interaction on a Web page, for example, is understood to be effective for certain work, in certain circumstances for a particular population. One such design problem is *the mapping problem*. Preece et al [20:23] characterise mapping as a relationship between a 'control', or component of an artifact, and its effect 'in the world'. Preece et al [19:716] characterise mappings as "how a description at one level of abstraction is translated into a description at another level." Green [13], when describing visual programming environments, has characterized mapping as the relationship between the world of the computer program (e.g. syntax, widgets etc.) and the problem world (e.g. having to write a sorting algorithm). Each of these characterisations of mapping have two things in common. Firstly they describe a relationship or coupling between two entities. Secondly they posit two planes or abstractions, which can be understood to be a physical or 'real' plane and a computer-mediated 'virtual' plane. Thus, the mapping problem is related to *the boundary problem* in mixed reality. A boundary marks the "joining together of whole environments" [4], where environments can be physical or virtual. A boundary can also apply to the division between the virtual plane embodied in a mobile guide and the real plane of the physical world. Benford et al. [4:207] raise a pertinent question with regard to mixed reality boundaries: "Will the boundary be completely transparent (i.e., freely allow information to pass across it), or will it alter awareness in some way, perhaps being more opaque?" With mobile guides, the boundary between what is in the system and what is in the world is at times blurred and permeable as the system augments the real world and vice versa. For example, an icon representing the user's current position, forces the user to map or augment where she thinks she is through being in a place through what the guide tells her with regard to her current position.

Here we explore the mapping problem with relation to context-aware mobile guides in use. We use two cases firstly to illustrate that mapping is a serious problem for mobile guide users and secondly to explore possible characteristics of this problem from the system perspective. Both cases involved evaluation of mobile guides in a real context through field studies. Through these two cases we discuss the consequences of failure to design for effective mappings: namely a failure to match users' expectations and a consequential loss of trust. We then propose possible interaction paradigms for mobile guides and a response to the mapping problem in the form of a matrix relating characteristics of mapping problems to interaction paradigms. Finally we utilize this matrix to reanalyze one example of a mapping problem and propose a new design based on this analysis.

2. CASE DESCRIPTIONS

This paper draws on two cases: the GUIDE project at the University of Lancaster, England and the Trammate Project at the University of Melbourne, Australia. The evaluations of the systems emerging from both projects will be focused on here.

2.1 GUIDE

The GUIDE project resulted in a tour guide application developed for the City of Lancaster. It was developed through the Department of Computing at the University of Lancaster. The GUIDE system integrated the use of personal computing technologies, wireless communications, context-awareness and adaptive hypermedia in order to support the information and navigation needs of visitors to the city of Lancaster. The GUIDE unit consisted of a customized Web browser. The system is described in more detail in [8]. The evaluation of the system utilized expert review and three field trials. These trials involved direct observation with users encouraged to think-aloud and subsequent semi-structured interviews. Sixty participants, between the ages of 10 and 70, used the system in these trials. No set tasks were given to the participants and they were invited to use the system only for as long as they wanted to. The trials took place around Lancaster castle in Lancaster.

2.2 Trammate

The Trammate project evaluated a functional prototype that integrated wireless communications, simulated location-awareness, a geospatial data service and a database of tram route information. The system supported journey planning for and travelling on the tram network in Melbourne, Australia. The system was developed by Jessica Smith from the Department of Geomatics at the University of Melbourne and designed to run within a PocketPC Web browser. Thus the system represented an integration of many services [26], but had limited location-awareness. The system is described in more detail in [26]. The evaluation of the system involved a field evaluation, laboratory evaluation [18] and heuristic evaluation [29]. The issues described here emerged from a grounded analysis [27] of the field evaluation data. The field evaluation involved five participants aged between 21 and 42. Three were female and two were male. These participants were asked to complete route planning tasks involving tram travel in the Melbourne CBD. All the users were frequent computer users, had some experience with using mobile devices and were familiar with the Melbourne CBD.

3. MAPPING ISSUES

In each of the two cases described above, issues with mapping emerged i.e. issues concerning some element of coupling or dependency between the mobile guide and the physical world. For example, in many instances the mapping between the user's location in the world (real) and the user's location as represented in the system (virtual) caused problems – this is similar to the problem instantiated by maps in shopping centres that indicate current position ('You are here') without describing *relationships* between current position and other things, such as landmarks.

The remainder of this section describes six characteristics of these mapping problems, emerging from the analysis of the two cases.

The analysis of issues with GUIDE is presented using miniature scenarios grounded in the field evaluations. The analysis of issues with Trammate is presented using extracts from the transcript of the field evaluation with appropriate background information. These extracts are presented as dialogues between the user and the evaluator.

3.1 Determination and indexicality

Determination and indexicality both refer to the 'just-enoughness' of the mapping between the system and the situation. Determination describes the intelligence of information provision and the constraints imposed on interaction with the system [29]. This will often translate into a context-aware system determining the information the user needs and how s/he should get it. Determination is similar to the notion of control in automation studies [23] and initiative in dialogue design.

Indexicality describes the broad contextuality of information: if information is provided in a context where it makes sense and in an appropriate manner given that context. Indexicality has been defined previously as "a property of an interface representation that is defined as having a context-specific meaning" [12].

Both determination and indexicality are "two-tailed". Information and dialogue can be over-determined and under-determined: the issue here is a fundamental design tradeoff between prescription and freedom/flexibility. Information and dialogue can also be over-indexed and under-indexed (these terms are illustrated with examples in the following sub-sections). Inappropriately indexed information can be very damaging for the user's understanding of the mappings within the system and can severely impede task completion.

3.1.1 Example 1: GUIDE

Mary is standing in the town square area (containing the Castle, Museum etc) but in the distance on the top of a hill she sees an interesting looking dome topped building that takes her interest. She presses the 'info' button but the system only gives links to the objects that are of close proximity.

In this example *what* is presented to the user is over-determined, in this case as a result of inappropriate indexicality. Specifically, proximity is used as the key determining factor for the list of attractions presented to Mary when a more appropriate factor might have been the attractions that were visible or more specifically salient to Mary when she pressed the 'info' button.

3.1.2 Example 2: Tram-mate

Sarah wants to catch a tram. She is standing on a street along which a lot of trams run. She queries the system in order to find out which tram to catch.

Evaluator: Did the system help you?

Sarah: No it didn't. Oh it is too. Thank you. Let's see what happens here. Okay. Enter departure time.

Evaluator: Yeah.

Sarah: Now. And waiting so it's…<u>I want to leave now. By the time it updates it won't be now anymore.</u>

In this example, *what* is provided to the user is under-determined. Sarah simply needs a tram number. The system has not determined the information to present to Sarah based on her location and the current time. Thus she expresses concern regarding the system's ability to provide the information she needs in time (underlined). The content of mobile guides can also be over-determined: pushing information to the user when s/he is still embedded in past interactions. Notably, in this example the information is under-indexed because the system does not deliver tram information based on the time and Sarah's location – it would have been more useful had it, for example, informed Sarah of all the trams leaving from the nearest tram stop in the next two minutes.

3.1.3 Example 3: Tram-mate

Kieran is trying to find out information from the system to help him to decide which stop to disembark from the tram he is currently on. Kieran chooses to view a map in the system to help him with this decision. The map is not detailed enough to assist him: it is a high level map with no low level detail.

Kieran: Oh, look at that map. What is the good is that map?

Evaluator: Does that help you?

Kieran: What the hell is that?

Evaluator: Does that help you?

Kieran: Nothin…What is it? I don't even know where it is.

Evaluator: Do you have any…?

<u>*Kieran*: I'm trying to get this fine detail between stop 5 and stop 8 or stop 6 and stop 8 and and it gives me this. That's great.</u>

In this example the indexicality of the information presented by the mobile guide is not appropriate. *What* is provided to the user is not indexed enough. Specifically, the information is not indexed to the user's current area of interest or region effectively. Thus the mapping between the guide and the real world is too abstract. Specifically, the user is unable to get detailed enough information to make effective decisions (underlined).

3.2 Accuracy & transparency

Accuracy and transparency both refer to the 'integrity' of the mapping between the system and the situation. Accuracy describes the correctness of information: if the information provided actually maps onto the physical world given the user's situation. The issue of accuracy is related to uncertainty [9], or the system's inability to understand a user's situation exactly. Transparency in groupware systems has been described as the degree to which "the system does not [or does] bring obstacles in the way of the task he or she is carrying out" [3:177]. This notion of transparency has also been applied to mixed reality environments to mean how easily information and users can cross boundaries between environments and the extent to which the system controls awareness and privacy. These definitions describe what we refer to here as the *how* of transparency. We define the *what* of transparency in terms of obviousness of the mappings between the system and the real world, or lack of these mappings. This includes the level of "honesty" that the system expresses and the visibility of its relationship with the physical world. Thus, in GUIDE, the information in the system was made more transparent by asking the visitor a question about her location when the system was uncertain about her location. Information can be over-accurate and under-accurate and over-transparent and under-transparent enough. A consequence of inappropriate accuracy is that subsequent system adaptation will be inappropriate [7:10]. A consequence of the system being under-transparent is that the user may 'lose' the mapping between the system and the real world, for example how her location 'in-the-system' relates to her location 'in-the-world' [9:4].

3.2.1 Example 4: GUIDE

John walks from the Tourist Information Center towards Lancaster Castle but the display of his PDA still reads 'Tourist Information Center' and when John presses the 'info' button information about the TIC building rather than Lancaster Castle is given – John comments that his trust for the system has been damaged.

In this example the mobile guide does not have all the information John needs to make sense of his situation. Specifically, John entered an area where no location beacons where received by his GUIDE unit when he approached the Lancaster Castle from the Tourist Information Center. This is a problem of accuracy, as *what* is presented to John is not correct, but there is also a lack of transparency - *what* was presented to John did not reflect that the system could not accurately determine his location.

3.2.2 Example 5: Trammate

Kieran is trying to catch a tram from outside a shopping mall. He uses the system to find out the tram he should catch. The system automatically detects his location, and asks him to verify his location.

Evaluator: Where does it tell you, you are?

Kieran: It tells me I'm on Bourke Street and Elizabeth Street.

Evaluator: Is that right?

Kieran: Ohhh, it's true enough. It's close enough.

Evaluator: Yeah?

Kieran: Yeah. I'd call that Elizabeth Street.

…

Evaluator: So what happened there?

Kieran: Well I don't see why it's interchanging. Ahhh, it thinks I'm so far down I should['nt] bother getting on a tram.

Evaluator: So what does the system tell you to do?

Kieran: <u>It's wrong. It's telling me to get on that stop there and go up to that stop there and that's silly.</u>

Evaluator: Why?

Kieran: Because it would be quicker for me to just go there.

In this example the mobile guide describes where Kieran should go, without acknowledging where he is. *What* is provided to the user is simply not accurate: the mapping between what is presented in the guide and the user's situation is not correct. The system describes how Kieran is at the intersection of the shopping mall and Elizabeth Street, when he is at the intersection of the shopping centre and Swanston Street, a block away from his location 'in-the-system'. Kieran doesn't think it's important at the time, but later the system returns a route that requires him to take two trams ("interchanging" in the dialogue), a tram to a place close to his current location and a tram to his final destination, when he knows he can walk to the tram stop to catch the second tram. This results in Kieran losing trust in the system (underlined).

3.2.3 Example 6: Trammate

Sarah is using a mobile guide to catch a tram from a particular stop. She catches the tram from the appropriate stop being driven by the system. Sarah is on the tram. She then consults the system again, looking for the tram she is currently on.

Evaluator: Is that [unclear]?

Sarah: No, no we have to get off at stop 10. Hold on, this has changed.

Evaluator: It's changed?

Sarah: <u>Yeah, we got on s… it's updated itself.</u>

Evaluator: Is it?

Sarah: Yeah.

Evaluator: What has it updated?

Sarah: It says we should be on tram 6 which is the one behind us. Except that originally we were on tram 5…it said to get on tram 5 but we're on [a] tram at the time that it said….

In this example, the *what* information given to the user lacks transparency and thus the mapping between the information in the guide and the real world is confusing for the user. Specifically the guide refreshes the tram route query without informing the user about the change, resulting in different information being presented to the user. This information is based on the stop the user caught the tram from, not on the tram Sarah is currently on.

3.3 Predictability: content and behaviour

Predictability is a useful but very broad term. It is therefore important, in the context of this paper, to distinguish between predictability of content (e.g. *what* a mobile guide may 'choose' to present to a user given the current situation) and predictability of behaviour (e.g. *how* a mobile guide may 'choose' to present a given piece of information to user given the current situation). Predictability of content can be regarded as relying upon the system providing compatibility at some level between the expectations of the user (gained through previous interactions and experiences with the system) situated in the real world and the information presented by the system. Predictability of behaviour can be understood as relying on the system providing compatibility between the expectations of the user engaged in a situation and how the information is presented, for example through choice of modality.

Cheverst et al. [6] describe how "When considering adaptation to context, designers should be careful to bear in mind the principle of least astonishment and the need for predictability." Predictability of content and predictability of behaviour are "two-tailed": a system can be both over-predictable and under-predictable with regard to content and behaviour. For example, under-predictable behaviour, in the form of unexpected dialogue or representations, may enable highlighting or emphasizing salient information by upsetting expectations or breaking the norms established through previous interactions with the user. A lack of predictability of content within a system may also break monotony and even increase learning through ambiguity [11]: a learner may be forced to discover information herself because of ambiguous content presented by a mobile guide.

3.3.1 Example 7: Guide

John returns to Lancaster castle for a second visit. The information presented is different to that presented on John's first visit some 15 minutes previously. On his first visit John was presented with a detailed description of the appearance of the castle via audio, text and images. This time John is presented with audio, text and images describing the history of the castle. John is not entirely surprised because he is aware that the system is recording the attractions that he has visited and adapting its behaviour appropriately (as would a human tour guide). John returns again 20 minutes later. This time John is a little surprised as he is only presented with an audio description of the day's events at the castle.

In this example, on the third visit the system decided not to repeat the detailed information about the Castle's appearance and history to John because in John's user model the system had recorded that this information had already been presented to John. Consequently, the 'intelligent' behaviour exhibited by the system involved only presenting John an audio description of the day's events at the Castle. Here the predictability of *what* is presented is medium: at some level John was expecting the information to be different on his third visit, but he may not have been expecting information on the day's events at the Castle. The predictability of *how* the information is presented is low, however: John had developed a model that information would be presented to him via audio, text and images. Thus, when he received a description via audio alone he was surprised.

3.3.2 Example 8: GUIDE

When trialing a push based version of the guide system, Jane was surprised by the following events. On approaching the Castle Jane was pushed an audio description about the Castle and again when approaching the town hall the system pushed another appropriate audio description. However, when approaching a famous antique plaque no audio description was given, but a textual description was given instead.

The obvious problem here is that from her actions Jane was building a model of the system's behaviour which was damaged when she approached the antique plaque expecting the system to push an audio description of the plaque. This was due to the fact that *how* the information was presented was not predictable: the information channeled to Jane was presented as text instead of audio.

3.3.3 Example 9: Trammate

Liz is standing at a street intersection trying to decide which way to go to reach her destination. She refers to a map to try to help her with making this decision.

Evaluator: Okay, how do you know what direction to go?

Liz: Umm, not, not because of the system, well because I've done, I've sort of caught the tram before ummm…I know that…let's have a look. <u>You see the last time we looked at the map we had destination on, but the destination's gone.</u>

In this example, the mobile guide has not been predictable concerning *what* it represented to the user of the real world: what is presented to Liz does not help her achieve her goals or relate to what she wants to do. We can also argue that *how* the information is presented is not predictable as the syntax of the map did not match Liz's expectations (underlined).

3.4 Comments on examples

Three additional issues emerge from the analysis above. Firstly, it is difficult to apply the characteristics of the mapping problem discretely: more than one characteristic can be used to understand the problem embodied in the examples. For example, in Example 8 the system is under-transparent in that the set of objects in the real world with a representation in the GUIDE object model is hidden: it is not transparent to the user. In this example, there is also a problem with accuracy: the system does not accurately model the physical world.

We do not consider a one-to-one coupling between problem and characteristic to be possible or even desirable. The goal of describing these characteristics is to understand key issues with developing context-aware devices better with a view to proposing solutions. There may be conflicts and tradeoffs when these characteristics are deployed, which is a reality of the design process [e.g. 14].

Secondly, the examples above have considered characteristics of mappings between the system and real world when place (e.g. landmarks) and events (e.g. time of departure) are involved in the mappings. In most of the examples the mapping issues are more complex, involving many more aspects of the situations described, such as user orientation, environmental conditions and personal variables. For instance, regarding orientation, in Example 3, involving the GUIDE system, the success of the mappings depends on exactly where Mary is standing and facing: she may not be able to see a key landmark, for example due to her orientation. The issue of orientation also emerged in the Trammate study, particularly when users were given walking directions to be followed after disembarking a tram. This caused one user to complain about the directions given by the system: "But it's told me the wrong thing. I don't want to go left. I have to go right." The effectiveness of mappings also depends on environmental issues such as if it is night and if the sun is shining. For instance, in Example 1 some attractions may not be as salient at night as during the day, making it difficult to utilize the GUIDE system effectively. The issue of environment also emerged in the Trammate study, causing one user to comment when looking at the PDA's display: "It's very difficult to see with the light." Personal variables can affect the success of mappings too: in Example 1, if Mary is short-sighted she may not be able to see certain attractions clearly. This issue also emerged in the Trammate study, causing one user to comment when using the PDA on a tram: "The other thing is, if I wear glasses I try to remember the street names and I don't really want to be worried about looking back and forth because I get confused if I look down at a small screen."

Finally, most of the analysis in the examples has focused on the *what* of the mappings in context-aware devices, or on the *content* of the mappings. However, for predictability, and to some extent transparency, *how* the mapping occurs seems equally important in the analysis. In Example 6, *how* the dialogue handles the transparency of the mapping is important when understanding the problem in the dialogue.

Acknowledging these limitations, we will now use the above characteristics to describe *interaction paradigms* for mobile guides.

4. Trust in mobile guides

Trust has emerged as an important issue in the design of e-commerce Websites [21, 10], online health sites [25], mobile commerce systems [24] and mobile guides [22]. Trust is defined as involving "two parties: the trustor and the trustee, reliant on each other for mutual benefit", "uncertainty and risk" and the trustor's "faith in the trustee's honesty and benevolence" [24:92]. A more technology-specific definition describes trust as "a multilateral relation, involving the technology…social partners in a direct interaction…a social context…experts, who have designed and developed a system,…who control a system, or who help the public to become aware of risks and trustworthiness" [22:3]. Riegelsberger et al. [21:122] critique current understandings of trust as focusing on cognitive aspects of trust and suggest that trust encompasses both cognitive and affective dimensions.

Given this short review, trust in a mobile guide arena seems to involve more than one party, with particular cognitive and affective peculiarities, involved in interaction, a technology and a social context. Trust also evolves and has discrete stages of development [24, 25]. Factors that influence trust in Internet and mobile commerce include familiarity, information quality [24], branding, usability, competence, security [10], personalization capabilities, user interface design, site architecture, user control [2]. There is disagreement regarding the relative importance of such factors [25] across domains, but some agreement that there is a need to explore these factors through appropriate methods and involving representative users [22].

We acknowledge that there are many factors influencing trust beyond interaction design. Our conjecture is that appropriate mapping is an important factor in initial trust formation in mobile guides. We also conjecture based on our studies that trust in the context of mobile guides is volatile: users' trust can be gained and lost and regained over a short period of time. To illustrate this, we again draw on data from the two cases described in section 2, above.

4.1 Trust and mapping

In the evaluation of GUIDE, Cheverst et al. [9] describe how particular ambiguous wording, such as "You are in the castle area" was used in dialogue with users in order to manage their expectations. This dialogue design emerged from experiences with wording that was non-ambiguous and under-accurate. [9] note such dialogue (e.g. "You are at the castle") had "lowered the trust of users" because the system had given an impression of accuracy that was not the case.

In Trammate, lack of trust emerged as an issue among users when the information provided by the system was inappropriate with regard to all six of the mapping characteristics described above and usually resulted in breakdowns in trust. This was despite the computer-savvy users generally approaching the system with an attitude of trust. As the evaluation involved about 90 minutes in the field using the guide it was not possible to evaluate long term trust development. However, some insights into initial trust formation and trust development were gained. Examples of trust breakdown, drawn from the data, are presented below, with a view to better understanding the connection between mapping characteristics and trust formation.

4.2 Trust and mapping characteristics

Regarding *determination*, one participant in the study commented: "Na, I don't believe it…Umm, why? Cos I know, I kinda of, I wanna go to my stop anyway, I think my stop's better. No matter what stop it's told me…" Thus the over-determination in the system regarding which stop the participant should catch a tram from caused the participant to question the system.

With regard to *indexicality* one participant questioned the trustworthiness of the maps in the system due to under-indexing: "It's just that I didn't trust the map telling me where I was at the moment." If information had been indexed to the participant's current location, this lack of trust may have been adjusted.

Under-*accuracy* also caused problems with one participant commenting: "Yeah, I don't think that's right because Exhibition Street's only two stops…So I can't really rely on that."

Regarding *transparency*, one user commented: "…but I wonder how accurate it's likely to be because we're going such a short distance." Another user commented "No the metres is, uhh, only if you think in metres but 7 metres is really hilarious. That means like just get up and go there. Get off and where you are, think if you got off at the back of the tram or the front of the tram that could be a whole lot of metres already used up. And maybe you wouldn't know whether you were allowed to walk past the front of the tram or not." In this example, the over-precise wording and measurement in the system contributed to under-transparency concerning the accuracy of the mapping.

One participant questioned the trustworthiness of the system due to under-*predictable content*: "It's just that I didn't trust the map telling me where I was at the moment. If it had told me the street names, I would have been able to figure out which way to go." This participant had been presented with information using street names up to this point. Thus the omission of street names caused her to lose trust in the system. With regard to *predictability of behaviour*, one user, surprised at the system's updating of route information provided, stated: "Yeah, but why did it change the route? That's stupid." The consequence of this was that this user continued to question the trustworthiness of the system for the remainder of the evaluation.

5. Proposed interaction paradigms

We have shown that trust relates to mapping issues. We now present five interaction paradigms that can be used to help design context-aware mobile guides. Possible generic paradigms have already been described above (e.g. guidebook). The aim of the paradigms below is to act like tools, affording the discussion of mapping issues when designing guides.

The five interaction paradigms presented below emerged from the analysis of the examples above. They are *guide*, *local*, *chaperone*, *buddy* and *captain*. These paradigms can be thought of as descriptive of possible mobile guides and useful abstractions for use in the design of future paradigms for mobile guides to ensuring that trust is at least considered during the design process.

5.1 Guide

The Oxford English Dictionary describes a guide as "a person who advises or shows the way to others" [17]. The *Guide* paradigm acts like a decision support system and can be compared to a guide on a hiking tour. A Guide exhibits "intelligence" through proactively making recommendations, and providing assistive information for example. The Guide paradigm also passes some initiative to the user during dialogues and filters information presented to the user. The second design of the GUIDE system exhibited Guide-like characteristics: it pushed the user information on opening times of attractions, for example.

5.2 Local

The Oxford English Dictionary describes a local as "an inhabitant of a particular area or neighbourhood" [17]. The *Local* paradigm acts like an information repository and can be compared to a local expert on a particular geographical area. The Local tends to be more passive than a guide: local experts often have to be sought out. Locals respond when queried, passing all initiative to the user during dialogues. Limited 'intelligent' filtering of information is used when responding to queries. The Trammate system exhibited characteristics of a Local paradigm: it accessed extensive tram timetable information and CBD geospatial data.

5.3 Chaperone

The *Chaperone* paradigm acts like an expert system and can be compared to a guardian [9]. When adopting the role of a guardian a system may only interact with the user if they are doing something wrong. Chaperone, like locals tend to be passive, although the chaperone may take initiative away from the user under certain circumstances. Thus, a high level of 'intelligence' is required to present information to the user. The chaperone is not really designed to be queried. The GUIDE system, for example, could have interacted with the user through using a chaperone paradigm by stating: "You are taking the wrong turning, you ought to go left, not right here."

5.4 Buddy

The Oxford English Dictionary describes a buddy as "a working companion with whom close cooperation is required". The idea of cooperation and shared responsibility for completing the user's work is important. A *Buddy* has elements of the expert system, decision support system and information repository. The Buddy utilizes mixed initiative dialogues, sharing control of the interaction with users. A Buddy exhibits a high level of 'intelligence' concerning its interaction with the user. A later version of the GUIDE system acted like a Buddy through asking questions such as "Can you see the castle?" Thus it adopted a cooperative stance when interacting with the user and utilized ambiguity in its dialogue.

5.5 Captain

The Oxford English Dictionary describes a *Captain* as "a person in charge of a team" [17]. The Captain acts like an expert system and uses an interaction paradigm similar to an on board navigation system in a car. Turn left Exhibition for 124 metres. Thus, the Captain takes initiative during dialogues and utilizes "intelligence" to filter information presented to the user heavily. Trammate exhibited the Captain interaction paradigm at times: it presented the user with directions which were termed in an imperative fashion e.g. "Go along Bourke Street for 7 metres."

6. Interaction Paradigms and Mapping Issues

Each of the interaction paradigms described above can be understood in terms of the characteristics of mapping problems. The table below maps the six mapping characteristics onto each of the paradigms, with a view to gaining a better understanding to leverage design for context-aware mobile guides. We corroborated this characterization of each paradigm through discussion. Some characteristics fit certain paradigms better than others: predictability of behaviour, for example, seems less applicable to the Local paradigm than the Captain paradigm.

Table 1. Interaction Paradigms With Respect To Mapping Characteristics

	Guide	**Local**	**Chaperone**	**Buddy**	**Captain**
Det	Medium	Low	Low	Medium	High
Ind	High	Low	High	High	High
Acc	High	High	High	Medium	High
Tra	Low	Low	Low	High	Low
Pre1	Medium	Medium	Low	Low	Medium
Pre2	Medium	High	High	High	High

Legend

Det	Determination	*Ind*	Indexicality	*Acc*	Accuracy
Tra	Transparency	*Pre1*	Predictability (content)	*Pre2*	Predictability (behaviour)

The table above describes how the *Guide* interaction paradigm is highly indexical and accurate, not very transparent, and exhibits quite high determination, predictability of content and behaviour. The Guide paradigm could probably maintain trust in stable situations where the domain is quite well-modeled. The *Local* interaction paradigm has low determination, indexicality and transparency and exhibits quite high predictability of content and high accuracy and predictability of behaviour. It is likely the Local paradigm would be effective at maintaining trust in stable situations where the domain is well-modeled. The *Chaperone* interaction paradigm has low determination, transparency and predictability of content and high indexicality, accuracy and predictability of behaviour. The Chaperone paradigm would probably be effective at maintaining trust in unstable situations where the domain is well-modeled. The *Buddy* paradigm has medium determination and accuracy, high indexicality, transparency and predictability of behaviour and low predictability of content. The Buddy paradigm is likely to be effective where domain is not well-modeled and the situation is unstable. The characteristics for the *Captain* paradigm are all high, bar transparency, which is low, and predictability of content, which is quite high. The Captain paradigm could be effective at maintaining trust in stable situations where the domain is well-modeled but the user is not.

7. Implications for design teams

Designing context-aware mobile guides for trust is difficult. Trust issues emerged even though the users in both the cases presented here generally approached the system with an attitude of trust. As described in [6] regarding GUIDE "The vast majority of visitors said they were prepared to trust the information presented by the system, including navigation instructions." However, these two cases have illustrated that trust often breaks down during interaction with context-aware mobile guides. The GUIDE project also showed that trust was volatile: "A number of visitors suggested that their level of trust was not constant but varied with the apparent accuracy of the information presented." In the Trammate evaluation, many users vacillated between trust and lack of trust when interacting with the system.

It remains to be investigated what the exact nature of the relationship between trust and mapping characteristics is. However, effective mapping shows *correspondence* between the system and the real world, i.e. information quality [24], and therefore the possibility of the user maintaining faith with the system. We argue mapping should be acknowledged within the design process by firstly acknowledging that there will be mapping problems and articulating these problems using the characteristics described here. We also believe designers should regard the artifact being designed as engendering trust and that the design will be fallible. Thus, when we create scenarios and artifacts for use within the design process, we should develop ones that test and explore characteristics of mapping problems. We acknowledge that the speculations regarding the appropriateness of the paradigms for particular domains of use, situation and user model require more exploration. For example, a *Captain* paradigm may be appropriate for factory engineers checking equipment, but not for a traveling salesperson moving between locations, where a *Local* paradigm may be more appropriate.

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