Information Representations for Shared Communication Spaces

G. J. DOHERTY(1), T. RIST(2), AND M.D. WILSON(1)

(1) CLRC Rutherford Appleton Laboratory, Chilton Didcot, Oxon. U.K.

(2) DFKI Saarbrücken, Germany

G.J.Doherty@rl.ac.uk, rist@dfki.de, M.D.Wilson@rl.ac.uk

In the design of distributed collaborative systems accessed by means of heterogeneous interface devices with different communication bandwidths, the manner in which information is represented in the interface is of fundamental importance. The designer must consider the level of detail and abstraction determined by the physical form factor, the integration of information from other external and communicated information sources (and representations), and the use of represented information in collaborative acts and communications. We examine these concerns with respect to a collaborative route planning and navigation system, and look at the distributed cognition approach as a basis for structured reasoning about information representations in the interface.

1. Distributed collaborative route planning and navigation.

An interesting and novel feature of applications based on emerging mobile and wearable user interface technology is the disparate and heterogeneous nature of the devices and capabilities available to different users. This is of particular importance for applications which support collaboration between users, who additionally may have different roles to play in the collaboration. In such scenarios, we see the interactive devices and infrastructure as part of the *distributed cognitive system* performing a task.

A good example of such a system is *MapViews* [7] in which a shared (city) map may be accessed by users using a variety of devices, with varying display and interaction capabilities, in order to perform collaborative tasks such as agreeing upon a meeting place and communicating a route to reach the meeting place. The display and communication capabilities of the devices determine both the amount of information which may be available to a user, and also the manner in which this information can be conveyed. For example, a PC user with a high-resolution display and a direct connection to an information server might have available detailed colour maps and numerous interaction facilities for navigation, annotation and so on, whereas a user "in the field" might have a small monochrome display on a PDA, or very minimal graphics on a mobile phone, accompanied by audio. Furthermore one can easily think of scenarios where different users play different roles, for example the mobile user might be a despatch rider (courier) and the PC user a central controller, who communicates with a number of mobile users. While we can conceive of many applications based on such "shared communication spaces", this application is particularly interesting since the information directly concerns the physical location and environment of the mobile user (core concerns in almost all mobile applications).

The problem we examine in this short paper is the question of how to design appropriate information representations on disparate interaction devices in order to support collaboration between users which is based on a shared communication space. An advantage of a focus on representation is that it allows us to improve support for a set of identifiable "core" tasks without proceduralisation which would make a device task-specific and reduce the possibility for opportunistic and unanticipated uses of the device.

2. Design and external information representations

A large body of literature supports the view that the way in which information is represented, external to the user has a fundamental effect on the users ability to perceive relationships within the information, and to reason about the information with respect to some task or activity [6]. Hutchins [5] goes further, and suggests that in collaborative tasks the appropriate unit of analysis is the distributed cognitive system of human and system actors, technological artefacts and external information representations. Thus the task of controlling the flight of an aeroplane is carried out by the distributed cognitive system of the cockpit, including pilot and flight engineer, system automation, information displays, charts, checklists and other resources exploited in the course of flying the aircraft.

This motivates an approach to interactive system design focussed on the representation of information - internal to the actors, on the display of the interactive system, and other external representations used by the distributed cognitive system in the performance of a task or activity. In this section we consider in turn a number of different concerns in the design of representations within the application area introduced above.

2.1 Form factor and information resources

Design constraints for a given form factor (mobile phone, PDA) are often quite severe, and effectively impose very strong constraints on the level of information and communication which is feasible. At this level, it may be useful to develop a model of the information to be communicated by the system, for example encoded as a set of classes. Consideration of device capabilities and the amount of information which may be conveyed through a given interface modality inform decision making at a very early stage of the design process - choice of a physical platform for the implementation.

In [7], a hierarchy of different levels of data is outlined, corresponding to the level of detail which can be supported by a given device. Thus we can range between devices with high communication and display bandwidth allowing very detailed and rich information displays, and more limited devices displaying only very abstract information. We can expeand upon this in a number of ways; the task domain may provide an ontology which can be used to discriminate different information layers, for example turns, route, landmarks, alternate routes, quality of route and so on. This is distinguishable from the "raw" data of a given level of detail. For example a mobile display for navigation might provide information on the next turn only, wheras a more detailed display can provide information on both next and future turns. This in turn affects the nature of the tasks performed by the user - in the first case attentional demands are high since the device must be consulted before each "decision point" on the route. In the second case, anticipation and future planning is possible, but error detection may be difficult due to the absence of distinctive features apart from the route.

Secondly, we can look at how these levels of information provide different resources for use in the distributed cognitive task. The *resources model* of Wright, Fields and Harrison [10] identifies a number of information structures which serve as resources in the use of a system; *plans*, *goals*, *possibilities*, *history*, *action-effect* relations and *states*. We can see detailed route information as an externalisation of a *plan* while for the movile device which provides only "next turn" information, the plan is for the most part represented inside the device. For the case where a user is being guided towards a destintation, the *goal* is externally represented in the detailed displays only if within the field of view, and not at all in the mobile display. *Possibilities* (affordances) refer to the actions available to the user - in this case taking turns, which can be seen both on the display and in the world. The mobile display is more limited in representation of these. *History* is externalised in the detailed displays and is absent in the mobile case. The *action-effect* relation is interesting since the detailed displays provide information on the effect of taking a turn, whereas the mobile does not.

	Plan	History	Possible	Goals	Action-Effect	States
Limited	No	Implicit	Partial	Separate	Possible	No
Detailed	Yes	Yes	Yes	Yes	Yes	Yes

Table 1. Available resources for limited and detailed displays

After such initial conisderation, the next step is to consider the different *interaction strategies* the user may take, and the resources these may use. Solitary navigation (as for example supported by in-car navigation systems) might be seen as a case of *plan following*. Obviously the plan is central to this strategy, but an aspect of the history - namely current position in the plan is also critical. Of interest is that this must be explicitly represented in the detailed displays, whereas it is implicit to the mode of use in the limited display. By contrast, tasks which encourage a *goal-matching* strategy make heavy use of the action-effect relation. For example a driver attempting to avoid traffic congestion may wish to take "equivalent" turns opportunistically, something which is supported by the action effect mapping in the detailed displays, but not in the mobile display. This suggests possible redesigns of the mobile display - for example to highlight "equivalent" turns. Similarly we may wish to consider whether the lack of a representation of goal or history in the mobile display is significant enough to task performance to warrant inclusion.

2.2 Information representation

While we may consider the effect of the above on the tasks which the user must perform, and the strategies he may take to achieve these, doing this requires that we commit to a given representation, since at each level of the hierarchy there will be many different ways in which the same information and level of detail may be communicated [11, 7]. For example consider the following two representations of route information on a device with limited display capabilities:

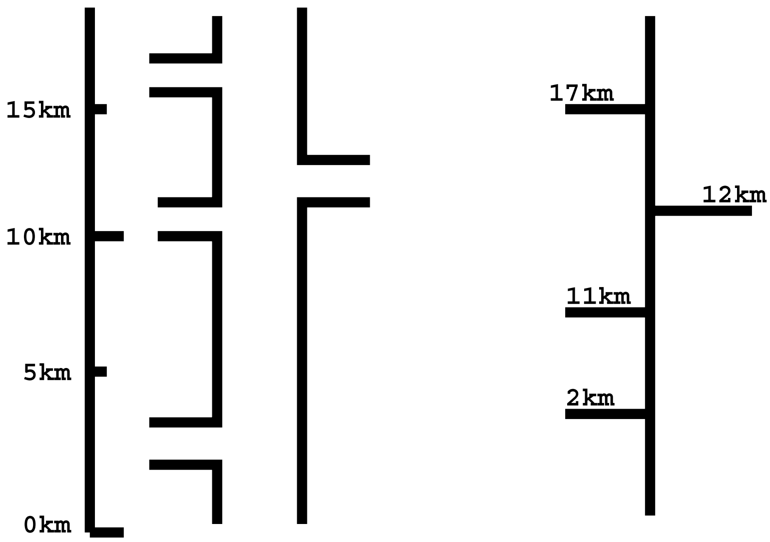

Figure 1 - Alternative information representations

In the first case, distance information is encoded in the relative spacing between turns and in their relationship to the overall scale. In the second case this information is represented numerically with only the ordinal relationship between turns encoded graphically. Which representation is most appropriate depends on both the tasks or activities of the user, and also on the other sources of information used in performing these. A formal framework for analysis of this task-perception mapping is given in [3]. For example, when driving on a motorway and using the tripmeter as another information source, the second representation may provide good support for the users driving activity, and specifically knowing when to expect the appropriate turning. Conversely a user on foot in a city centre might find the first representation more useful as the comparison is with the turnoffs they can see at that particular point. Only by considering the other external information sources (and hence representations) available to the user can we make a decision concerning the appropriateness of a given representation.

At this level, we may wish to note those relationships within the information which should be easily perceivable in order to support the users tasks. Some structured descriptions of user tasks and activities may also be useful.

2.3 Shared Representations

One of the fundamental difficulties with such collaborative applications is that there may be some mismatch between internal representation and physical world, or between internal representations of different actors. Such a mismatch becomes significant when the user performs an action (such as making a turn, or communicating), which is dependent on this information. In such a situation actions can either reinforce the belief that these representations and/or artefacts match, or they may expose discrepancies between them. The question one might then ask is how can we minimise the former and maximise the latter. Some domains use solutions such as verbal protocol, and it is interesting to consider how such protocols might be designed with respect to particular situations, such as "re-orientation" (establishing a new frame of reference ie. direction) and "synchronisation" (eg. a communication which confirms the equivalence of shared information). However outside domains where regulation, training and social factors ensure conformance to such mechanisms, we could ask whether we can achieve the same desirable dialogue properties by means of the system design, and particularly the representations used.

The Environmental Interactive Systems approach of [9] attempts to address the issue of shared representations, between co-located users using physical artefacts.In the model, the conception a user has of information perceived by other users is considered, along with physical and informational aspects of artefacts. In a similar manner, by identifying the links between internal and external representations, and the ways in which these are used in performing a task or activity, we can consider the significance of user actions with respect to these representations.

Consider a scenario with the MapViews system where a mobile user is having difficulty matching the directions on the mobile device to the appropriate route in the real world, and makes a query to some central controller with access to a detailed display. When one considers the task facing the pair: the mobile user must include in the query information regarding what they can perceive in the environment; this must be mapped to an orientation by the controller, who can then relate this to the detailed display in order to generate an appropriate response for the mobile user.

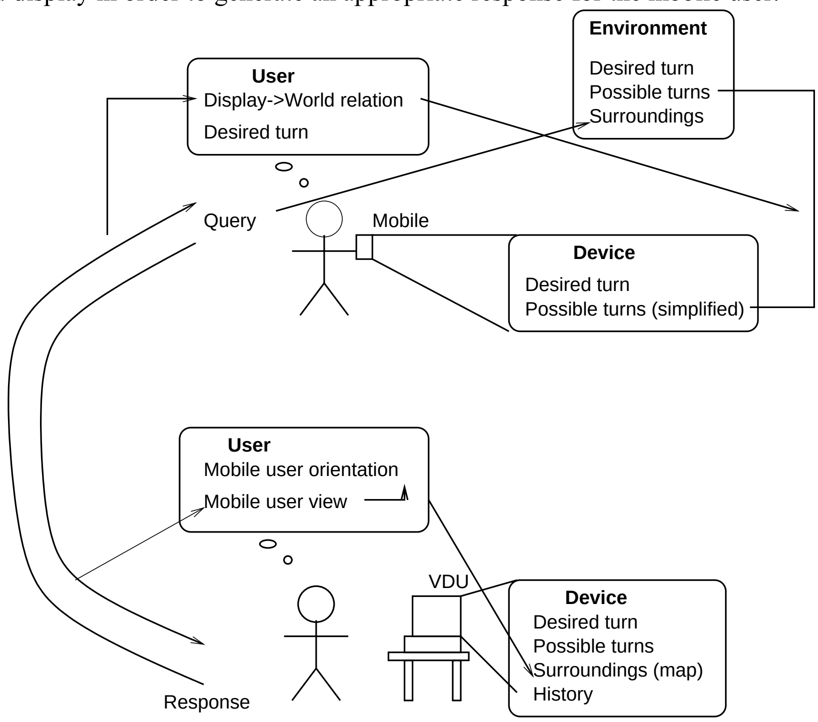

Figure 2 - Internal and external representations

From this we see how a piece of information not directly included in the presentation (orientation) is used and integrated with other information in the task. Consideration of this leads us to conclude that the mobile users most recent movement history is likely to be useful for this purpose and might hence be given emphasis in the presentation. Thus it can be useful for models at this level to encode relationships between representations and user actions, as well as between different artefacts and represented information.

3. Intelligent system support

The issue of intelligent support for choosing information representations has received some attention in the past. Casner [2] looks in particular at the dynamic generation of information presentations; one can easily imagine a context sensitive system which would choose an appropriate representation based on the users tasks or activities and environment. However there are also disadvantages to such an approach, since the displays generated may not conform to the users expectations in terms of display conventions, for example where there are common or standard representations for information (eg. a railway timetable). Another limitation of intelligent system support concerns the ability of the system to infer whether eg. if the user is lost, since the users own knowledge of routes, one-way systems, traffic, road works and diversion routes mean the system (or central controller) may lead them to take a seemingly less desirable alternative (eg. a cyclist might choose not to cycle over a hill, information not usually included in urban maps).

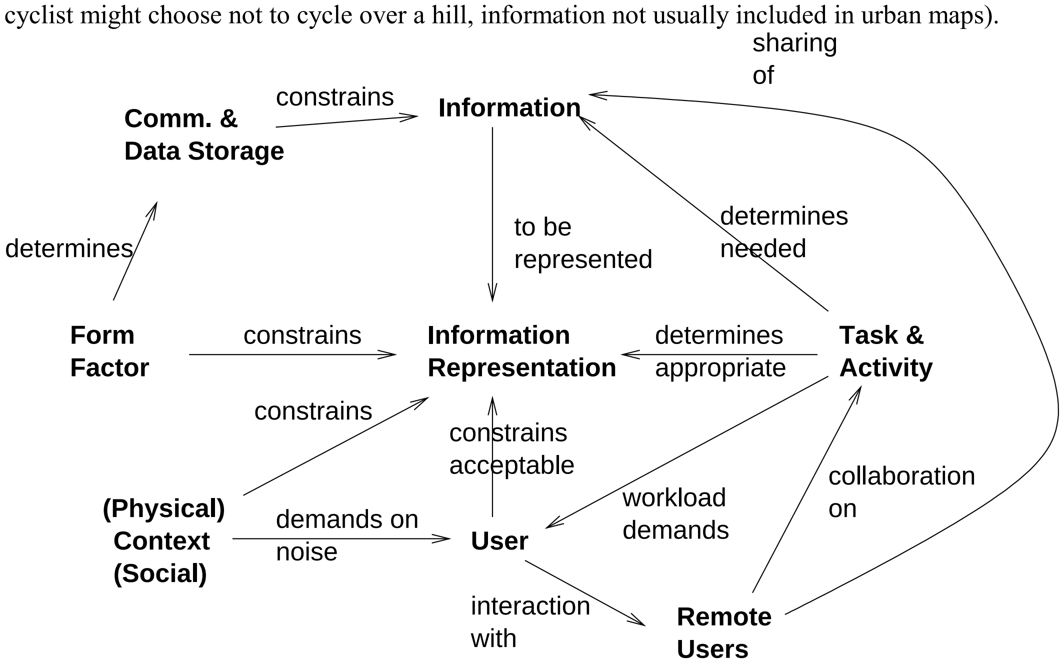

Figure 3 - Factors influencing choice of information representation

A further difficulty, there is the question of when changes in the users task-activity or environment are of sufficient degree to justify a change in information representation. For example, when a driver leaves a town and joins a motorway, a different representation of route information might be appropriate. The idea of plasticity [8] interesting in this context - here it is the representation and information represented which has a certain degree of plasticity with respect to task and environment, rather than the device itself and/or the users ability to use it. Conversely, this variability, and the dependencies between factors influencing the choice of representation may provide significant motivation for intellident support for adaptation. A sketch of some of these factors is given in figure 3. Note that task and activity *may* change, physical and social context *will* change, participants in a collaboration are *likely* to change, and also the users *role* in collaborations may also change. In terms of intelligent system support this is quite a challenge since an approach would need some modelling of social and physical context, and the manner in which this affects user attention, workload, and the suitability of interface modalities. Likewise some form of task and activity modelling may be necessary, along with the demands this also places on user workload. In this vein, [1] suggests a scheme for dynamically modelling such complex factors in the context of an active driver support system.

4. Conclusions

In the sections above we have shown how the focus on representation of the distributed cognition approach, and specifically the resources model of [10], can allow us to approach the design of complex mobile collaborative systems in a structured way. We have show how such an approach can help us to choose between representation design alternatives, to identify weaknesses with respect to support for given tasks, and to suggest ways in which these weaknesses may be addressed. We have briefly considered the challenging issue of intelligent system support based on such approaches. Other issues include location [4], and time. In the immediate future we will be exploring the use of modelling in UML to support reasoning about these issues.

This work was supported by the TMR TACIT Network, Contract no. ERB FMRX CT97 0133.

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