

COMMUNICATION ABOUT SPACE

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We all do it: we all communicate about space and we do it with ease as one of our most basic natural abilities. Even animals do it - for example, bees as they dance to communicate distance, direction and the quality of a food source. Humans utilize a variety of senses and channels for communicating about space, among them the use of spoken and written language, gestures, sketches, or the gentle physical force when taking a person by the arm or leading in a dance. In addition, we have learned to interpret the language of experts communicating about space – such as in maps (cartography), posted signs (semiotics) or the affordance of designed spaces (architecture).

Which brings us to Geographic Information Systems (GIS) – advanced tools to analyze complex spatial and dynamic interrelations, and to display them in forms such as maps, graphs, tables and reports. Such results are an essential means of support for complex choices, as made by experts or by decision-makers studying the advice given by experts. However, I want to focus here on a relatively new group of GIS clientele – the broader public – and to examine how GIS communicates for *everyday decisions*.

Everyday decisions

Everyday or routine decisions are made based upon skills everybody has and no special expertise is required beyond common sense. Looking at everyday spatial decisions, people might seek support by asking questions such as “Where am I?” “Shall I go left?” “Where is the next café?” and “Is there a train connection in the afternoon?” Everyday decisions are to a high degree automated, which means they are made quickly with low cognitive effort. Furthermore, such questions are posed in specific contexts. For example, a car driver needs wayfinding instructions in a different form (and based on different data) to a pedestrian tourist or a business traveler. Services made to support everyday decisions must take this critical element into account, but we should also note there are fluent or smooth boundaries leading to more complex decisions and services. For example, trip planning has occurrences that might be considered everyday decisions (because everybody does it), but it has also occurrences that require expert skills (which is why travel agencies are in business).

Specialized GIS designed to support spatial everyday decisions, and from the perspective of a specific user group, were once termed *Small GIS* (Frank 2000). However, while the name characterizes the narrow focus of the system, we should not be misled into assuming the problem to be solved is a small one. Indeed, Small GIS need entirely new means to communicate about space because their clientele seeks decision support recognizable with low cognitive effort – that is, by a means that communicates immediately.

Unfortunately, it is not easy to teach a computer to communicate about space in a manner closely resembling human communication. Let me start with a test question. Imagine you are

arriving by train in a foreign city, you have an address to go to, and you speak the local language. In this situation, which help would you look for:

- asking a local person for the way to the given address? or
- dialing a mobile wayfinding service advertised in the station hall, and trying to figure out how to handle the service?

Certainly, the question is suggestive, but remember that outside our mobile GIS community people *are* prejudiced. Simplistic services with complicated interfaces shift the cognitive activity away from solving the wayfinding problem to solving the human-computer interface problem. Clearly, such services cannot be an economic success.

Human generated wayfinding instructions

For a fairer comparison, take the example of human generated wayfinding instructions. On a recent trip I arrived in a foreign city by train and my host had provided me with the following route description: “*Here is how you will get to my home by bus from the train station. After you leave the train station (take the main exit ‘West’, not ‘East’) continue across the square leaving the big glass house on your left side (containing the bike parking), and cross the main road at the traffic lights ...*” I can say now that this human generated instruction was a success since on that day myself and several people all found our way to the same address and reported no difficulties following this description. So it communicates well¹. We recognize here some general characteristics of human wayfinding instructions:

1. they are typically qualitative with no reference to geometric measures;
2. they make extensive use of landmarks; and
3. senders put themselves in the position of the receivers.

Computer generated wayfinding instructions

In comparison to the wayfinding instructions above, let us assume I found a Web terminal in the train station (a mobile service was not available). I would have received a description in two parts: a map showing the whole route, and a verbal description (Figure 1).

Start: Bahnhofstr. D-48143 Münster				
Hr.	Type	Description	City/Distance/Journey time	MiniMaps
1.		You start at Bahnhofstraße (K9), Münster (D-48143) and head towards Urbanstraße for 140 m (150 yards).	Münster 0,0 km (0 yards) 00 min.	<input type="checkbox"/>
2.		Leave the Bahnhofstraße (K9) and bear left to the Urbanstraße for 140 m (156 yards).	Münster 0,1 km (150 yards) 01 min.	<input type="checkbox"/>
3.		Leave the Urbanstraße and bear left to the Von-Vincke-Straße for 150 m (160 yards).	Münster 0,3 km (306 yards) 02 min.	<input type="checkbox"/>
4.		Leave the Von-Vincke-Straße and continue straight onto the	Münster	<input type="checkbox"/>

Figure 1: Computer generated route instructions for the same route (© Netsolut GmbH 2004 for Map24).

Let us generously leave aside two otherwise important aspects: that this route instruction starts at a different anchor point (in front of the station, instead of disembarking from a train);

¹ In case you are interested *why* this instruction communicates well, stay tuned – there is a corresponding paper in preparation.

and that it assumes a different travel mode (driving a car, instead of taking a bus). What remains are the observations that this type of instruction is based on quantitative geometry and street network topology, it makes no reference to landmarks, and does not take too much account of the position of the message receiver.

Therefore, if these requirements appear so elementary to human communication, why is it so difficult to teach this to a computer? The explanation is that there is no obvious mapping from a map-oriented technology to a ‘talking’ or ‘natural language’ technology. Let us stay with car navigation systems as a convenient example. The first generation car navigation systems showed maps on little screens, and failed to communicate well because a car driver should not (for good reasons) be looking at a screen when driving. The current second generation systems do it better, showing only simple sketches and for the rest speaking in natural language to the driver. Some of these systems permit switching between passenger (map) mode and driver (large arrows/simple directions or spoken instructions) mode. Certainly, you can argue this was not really difficult to achieve – after all a routing algorithm identifies a sequence of nodes and edges which can be written as a sequence of statements in a formal language using a strict grammar (Frank 2003). The formal language then assembles the input to a natural language generation system, and in turn to text-to-speech software. So, there you have it! Nevertheless, in practice it is not so easy to achieve, as has been shown by the comparison above.

So why worry?

Here are some thought-provoking factors about why we need to be concerned with resolving this problem:

1. Oddly enough car navigation systems are – to my knowledge – the only ‘talking’ systems. It seems the approach described above only works in limited contexts (for example, driving a car) and for simple communication tasks (sequential sentences). Most other systems rely on graphical output, conventional maps, or map-like representations. Even Location Based Services (LBS) depend on graphical output, even though they are operating on mobile devices designed for verbal communication and the screens were never intended to serve that purpose.
2. Although the usability of car navigation services could be considerably improved, wayfinding success is still not guaranteed (and the reasons for this are not just because of communication problems). People do not find what is referred to in the text, they make decisions different to the ones intended by the service, or they simply have difficulties matching what is heard with the reality they perceive with their other senses.
3. Furthermore, systems enforce the use of their language and thus their spatial concepts. But people are individually different; they have different spatial abilities, various *a-priori* knowledge of space, various interests and level of attention to their environment, and different intentions when moving through an environment.
4. Finally, communication is strictly one-directional. Do not try to talk back your car navigation system. Even if it had an in-built speech recognition system it would still have extreme difficulty interpreting human spatial expressions correctly.

Current research directions

Research relating to this problem is typically undertaken not in traditional GIS disciplines (such as geography), but in psychology, cognitive science, neuroscience and linguistics. Also contributing from another perspective is computer science with links to artificial intelligence, virtual and augmented reality, robotics and human-computer interface design. Good resources for recent progress in this field can be found in the three volumes on *Spatial Cognition* (Freksa et al. 1998; Freksa et al. 2000; Freksa et al. 2003), or the proceedings of the conference series on *Spatial Information Theory* (Frank and Kuhn 1995; Hirtle and Frank 1997; Freksa and Mark 1999; Montello 2001; Kuhn et al. 2003). Let me randomly select some lines of research that are relevant here, and discuss their potential effect on future interface designs to geographic information services.

GI Science. The traditional approach to communicate spatial information is by maps – which are highly specialized information products to support decision making on specific questions. The map-making process is founded on heuristics, not on theory. Hence, there are *good* maps, but not *correct* maps, to answer specific questions. This means that maps are a communication means – they are carriers of signs – to transport a message from a map designer (typically a GIS expert) to a client (typically a person skilled in map reading). Communication success by maps can be measured by observing what the designer wanted to represent, compared to what the map reader understands. A similar approach leads to measures of information content of route instructions (Frank 2003), which essentially refers back to information theory (Shannon and Weaver 1949). With a formal measure of information content, we will be able to control the level of redundancy in communications about space. It would be interesting to investigate the level of redundancy people feel comfortable with.

Augmented Reality. Cartographers also go beyond traditional maps to communicate by new media, the Web or mobile devices. For a good overview see another editorial in this journal (Cartwright 2004). Their instruments merge more and more with Virtual Reality (Mallot et al. 1998; Schilling and Zipf 2003) used to learn an environment, or Augmented Reality (Reitmayer and Schmalstieg 2004, see Figure 2) used to guide movement within an environment. With many people having difficulty reading maps, communication via information projected into the client's visual field might reduce the cognitive workload of matching and interpretation. However, these systems require a learning phase and additional equipment. Nevertheless, it would be interesting to teach them 'talking' as support for the visually-presented information.

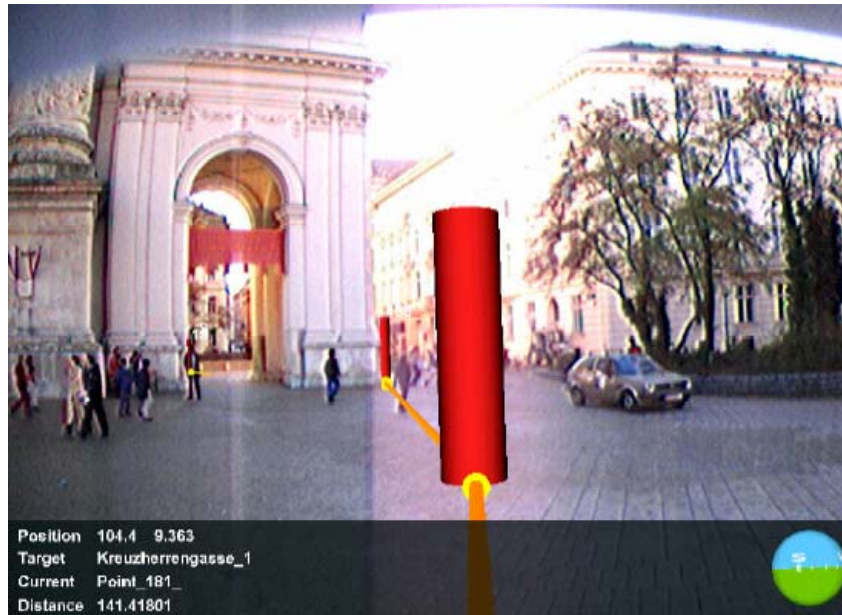


Figure 2: Communication of route instructions in an augmented reality interface (from Reitmayr and Schmalstieg 2004, re-printed with permission).

Psychology. We need to determine the principles associated with how people communicate about geographic space. Given a number of sets of route instructions for the same route, we could compare them and identify their highest common factor or skeleton. Vice versa, the success of the skeleton might also be tested (Denis et al. 1999). It has also been shown that landmarks play a central role in human communication. These landmarks are chosen at specific places along a route – its decision points (e.g., Golledge 1999; Michon and Denis 2001). Other questions arise as to what a landmark defines, and what kind of landmarks communicate best (Tom and Denis 2003)? All this work then needs to be transferred into computational models. With a characterization of the salience of features by visual, structural and semantic properties, it might be demonstrated that automatic selection of features is capable of identifying the most salient ones (Nothegger et al. accepted). This model is even capable dealing with different client contexts (Winter et al. 2004), although open issues still remains in how to automatically identify the skeleton of a route, and how to best communicate the identified salient features.

Language. The last point of my arbitrary selection of topics regards language aspects. A relatively new keyword appearing on conferences is the spatial narrative – which is the approach taken to automatically produce spatial descriptions that come close to human concepts, for example that reflect the characteristics of the skeleton of a route description (Dale et al. 2003). There are also computational (logic-based) frameworks for qualitative spatial reasoning available (Frank 1996; Renz 2002), which can help describe situations in a qualitative way. Furthermore, as we have seen in our first example, it needs to take the position of the moving clients into account when describing space (Klein 1982; Retz-Schmidt 1987), and to use the language of the clients – the verbs of their current activity and the nouns of features that are relevant to their current activity (Timpf 2002).

Talking about space

Finally, I hope I can make you more curious about this exciting area of GI Science: how to talk about geographic space. Certainly, the topic is far from solved and from my perspective there are at least two challenges in this subject that will keep researchers busy for the next few years:

1. the integration of computational models of cognitive processes of different senses and levels of spatial granularity, and
2. the introduction of bi-directional communication. The most natural communication is the dialog.

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