# Intelligent Spatial Communication

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## Abstract

How far are current route services from imitating humans in giving route directions? And what can we learn from this question, in terms of gaps of knowledge and need for further research? This paper aims for a systematic framework to develop a research agenda for services to give better route directions. The paper starts from the premise that people can give better route advice than current route services due to their richer language, their more compatible spatial concepts and conceptualizations, and their inferences during communication to capture and adapt to context. The framework is developed from three perspectives on human wayfinding communication. Services still have a long way to be able to imitate human route communication behavior.

## 1 Introduction

Consider the simple question of a person: “Can you tell me the way to ...”, which leads to typical everyday communication either with other persons or with a computing machine in form of a dedicated navigation service. Current navigation services are frequently criticized for not adapting to the user’s needs and language (e.g., Timpf 2002; Pontikakis 2006).

Recent progress in technology has evolved along two directions. One is towards dynamic proliferation of more content, such as real-time traffic data, points of interest, or find-and-recommend services. The other is towards more complex interfaces, such as perspective views, 3D, textures, or multi-modal information. These developments seem to counteract easing the cognitive workload of the user, and the question arises whether more intelligent services can evolve at all from these directions of current development. With other words, does research and development need a correction of perspective? This chapter sets out to study what makes a truly intelligent navigation service.

Turing, laying the ground for what later became known as artificial intelligence, starts his landmark paper *Computing Machinery and Intelligence* with the words: "I propose to consider the question, 'Can machines think?'" (Turing 1950, p. 1). This question seems appropriate in the current context, where we are seeking what can make navigation services intelligent. Hence, we take the liberty to restrict Turing's question by asking "Can machines think spatially?".

Already Turing himself was aware of the problem of defining thinking or intelligence. He came up with an elegant suggestion: an anthropomorphic imitation game, which was later called the *Turing test*. In this game persons are supposed to find out whether they are communicating (via teletype) with a machine or another person. Turing equaled anthropomorphic communication behavior with being intelligent. If the player cannot distinguish between machine and person the machine passes the Turing test.

We may borrow from this idea. Translated into our context, a machine can show intelligent spatial communication behavior if persons, requesting some route information from the machine, cannot find out whether they are communicating with a navigation service or with another person. To be generous—extending Turing's rules of communication—we might even allow for graphical (Egenhofer 1997; Agrawala and Stolte 2001) and gestural (Kopp and Wachsmuth 2004; Cassell et al. 2007; Roth 2007) communication interfaces, since people may describe routes graphically and by gestures as well.

Others have limited the scope of the Turing test before. For instance, the Loebner Prize[1] is awarded annually to a program that passes a Turing test *of limited scope and tenor*. In our context, the scope would be restricted to the domain of orientation and wayfinding, and the tenor to a natural discourse in this domain. We do not require a navigation service to be intelligent about other domains, let us say, football or food, and we also do not expect navigation services to cope with attempts to be outwitted.

The communication behavior of a navigation service can be tested for the conveyed *information content*, i.e., whether it is delivering appropriate routes, and for the *form of communication*, i.e., whether it understands the user and responds in terms and references a person would choose (Allen 1997). But even a service that behaves reasonably well content-wise and

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[1] http://www.loebner.net/Prizef/loebner-prize.html

language-wise on standard requests requires flexibility to be able to follow the course of a natural conversation on orientation and wayfinding. Persons may come with a variety of requests such as for more detail on a route, for alternative routes, for confirmation of their understanding of a route description, for comparisons or assessments, for clarifications of perceived inconsistencies, or for context-dependent additional information such as fares or kinds of tickets.

Spatial communication fails to be intelligent every time when an anthropomorphic quality in a service's communication behavior is detected missing. Since the total number of missing qualities cannot be determined, it is impossible to prove that a machine can behave in their spatial communication like a person. But each closure of an identified gap forms a refutation of the hypothesis that machines cannot behave like a person—until the next gap is detected.

Looking at intelligent spatial communication this way, it provides a vision for an intelligent navigation service, something that current progress of technology is lacking. We suggest a test for intelligent spatial communication behavior as a benchmark for research and development in this sector, facilitating a clear criterion to separate new features filling a gap towards an (in Turing's sense) intelligent navigation service from others added rather as unique selling points. The aim of this paper is to establish a formal framework that will enable us to study the state of the art and gaps towards intelligent navigation services.

This paper starts with developing the concept of the test (Section 2). It then studies the human wayfinding communication process from different perspectives. The first perspective looks at the phases of the communication (Section 3). The second categorizes the elements of the spatiotemporal context of a wayfinding communication (Section 4). Finally, the third perspective is taken by identifying characteristics of an intelligent agent for the communication partner of the wayfinder (Section 5). The paper will conclude with a summary and outlook (Section 6).

## 2 A Criterion for Intelligent Spatial Communication

When Turing (1950) suggested the anthropomorphic imitation game he was interested in finding a simple operational definition of intelligence. Nevertheless, his suggestion of the game (now called *Turing test*) sparked an ongoing controversy in artificial intelligence and beyond[2]. This controversy entwines around the notion of *thinking* or *intelligence*.

So, is it *intelligent* if the computer imitates a person successfully? Philosophers, for example Searle, insist that thinking requires a mind and consciousness. Searle's Chinese Room experiment (1980) basically says that a computer programmed to do a task (here: understanding Chinese) could also be replaced by a person running this computer program by hand. As this person does not understand Chinese, nor does the computer. With other words, digital computers are mindless; they manipulate symbols in an order they were programmed. Already Lady Lovelace (after Turing, 1950) realized that machines can only do what we have the skill to tell them to do. Even though a program adds abilities and programmers' knowledge to a computer, potentially including an ability to learn and hence to act in ways not predictable by their programmers, this teaching of abilities and know-ledge only means a computer can be appropriately programmed to pass the Turing test (what Searle calls weak AI), without a chance to claim having consciousness or a mind (what Searle calls strong AI and links to thinking and intelligence). Obviously the Turing test relies only on the communication behavior, i.e., the cognitive and linguistic performance capacities of a digital computer. It does not require to look like or to internally function as a human. Accordingly, we will abstain in the following from using the word thinking, and render our expectations more precisely as an imitation of a person's spatial communication behavior. This means we call a service intelligent if it appears in its spatial communication behavior like an intelligent agent: a person.

But the initial question can also be phrased slightly different. People may ask whether the computer is not more intelligent than a person anyway, so why bother with imitating? Where this question comes up, the objectivity of a computer and its large and accurate data sets seems to be able to generate more trust in spatial advice than a fellow citizen. However, this question shifts the focus from intelligent behavior to behavior superior to the human mind. The computer is superior to the human mind in at least two ways:

- A persistent and large memory enables a computer theoretically to access a complete and accurate travel network data set for route computa-

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[2] French (2000) observed that Turing's paper became the most discussed paper in artificial intelligence, and Crockett (1994, p. 1) notices: "Andersons's 1964 anthology, Minds and Machines, places Turing's paper first, perhaps following the ancient Semitic practice of placing the most important literature in a collection first".

tion, which can be even kept up-to-date by distributed sensors. A person is always bound by knowledge acquired by experience over time.

- Algorithms to compute optimal routes can be shown to be (theoretically) correct. A person is bound by distorted cognitive spatial representations (Stevens and Coupe 1978), and human route selection is habitual and applies heuristics that potentially lead to suboptimal routes (Golledge 1999).

Now, superiority, once detected by a human communication partner, leads to failure in the Turing test. With other words, in Turing's sense it is not considered to be intelligent. Although this conclusion may surprise, there are arguments why an intelligent navigation service should not demonstrate its superiority. These arguments are based on cognitive costs:

- It has an advantage why people do not (always) select the route optimal according to a cost function. Their selection is based on rules of thumb. Gigerenzer (2007) calls such rules of thumb convincingly the intelligence of the unconscious, referring to the delusion of finding an optimum in an uncertain world (even a computer is limited in finding an optimum facing the unpredictability of travel times in the future). People may favor simple paths or familiar ones and by this way ease their wayfinding process, including the communication of the route.
- It has an advantage when people sketch routes verbally or graphically, concentrating on essential and relevant route properties and relations to the environment. Communicating by maps, metric information, perspective views or virtual reality animations—showing as much detail as possible, as many navigation services do—comes at costs. The wayfinder has to make special cognitive efforts to understand and realize these route descriptions. Map reading is known to be a complex task, and maps provide information about a whole area, i.e., far more information than required or expected for a route description. Metric information is difficult to realize and has issues with granularity. Views and virtual reality animations are different from the embodied experience of the wayfinder in perspective, detail, light and street life.
- It is advantageous when people communicate routes by flexibly referring to cognitively salient features or properties, in contrast to references to travel network segments and nodes, the navigation services' primary data resource. Route information from people is more memorizable, and typically shorter.

This argument means consequently that people are superior to computers in (in principle being able to) choosing more *appropriate* routes and route descriptions. Even more, they do this relatively effortlessly, and we are far from knowing how to tell the computer to replicate such skills. By no means it is claimed here that human route descriptions are per se more appropriate. Routes chosen and described by people can fail, can be far from any optimum, or can be ambiguous. But since other examples exist as well—human generated appropriate route descriptions—such properties do not need to be copied by a machine to be called intelligent.

If we now agree on the desirability of navigation services capable of intelligent spatial communication behavior, finally a third question has to be answered: Can a computer ever successfully imitate a person?

Crockett (1994) approaches this problem referring to the frame problem. The frame problem is the problem, given a dynamic world, of how to limit axiom revisions in logical systems (McCarthy and Hayes 1969), or more generally of how to limit the updates of beliefs about the world given that the world changes or we interact with the world (Pylyshyn 1987). Assuming that a system knows the states of the world at a time $t_0$, then at time $t_1$ changes have occurred. Some of them may be known to the system and can be introduced by axiom revision, but what about the other states? The frame problem is especially relevant in a dynamic domain such as wayfinding.

Crockett points out that a computer, to pass the Turing test, has first to solve the frame problem. He argues that, since a solution of the frame problem is not in sight, the answer to our third question has to be a probably no. All this can only mean that a requirements analysis for an intelligent navigation service is always tentative. An intelligent navigation service can only be approximated.

The following three sections will develop a systematic framework to study the desired characteristics of an intelligent navigation service. The sections will combine three independent approaches to wayfinding communication. One is about the phases of wayfinding communication and the individual tasks of the communication partners during these phases. The second is about the spatio-temporal context of wayfinding communication, and the extent to which it is considered by the communication partners. The third approach is about the characteristics of an intelligent autonomous agent, to be able to imitate their communication behavior.

## 3 The Phases of Wayfinding Communication

Klein (1982) and Wunderlich and Reinelt (1982) have studied the human wayfinding communication process. They identified four phases in this communication between a wayfinder and an informant:

1. the *initial phase*: a wayfinder asks an informant for directions,

2. the *center phase*: the informant provides route directions,
3. the *securing phase*: either the wayfinder or the informant want to make sure that the wayfinder has understood the given route directions, and
4. the *closing phase* of closure and separation.

Nearly all research so far focuses on the center phase, studying either route directions provided by people (e.g., Klein 1979; Denis 1997), or studying how route directions can be generated automatically (e.g., Dale et al. 2005; Richter 2008). This is the only necessary phase; the other ones are optional. An extreme example might be the printed travel guide, providing a route description to the reader without a specification of a request by the reader, without a securing phase except that the reader can read repeatedly, and without a closing phase other than that the reader closes the guide book or turns the page, i.e., averts his attention.

At each stage of the communication Klein (1982) as well as Wunderlich and Reinelt (1982, p. 183) identify three subtasks present. These subtasks are:

1. a cognitive task (e.g., activating a spatial cognitive representation);
2. an interactional task (e.g., initiating and terminating the verbal exchange, or providing a route description);
3. a linguistic task (e.g., expressing a comprehensible route description).

Interaction between the cognitive and the interactional task, in the context of a machine as informant, includes not only the cognitive abilities of the wayfinder, but also the internal data models and algorithms of the navigation service. Between these tasks the focus is on identifying and modeling the references that have to be conveyed and understood (the content). The third task focuses on their actual representation in a specific sign system (the language). We allow for different sign systems (teletype or graphics, and if teletype then any spoken language).

### 3.1 The Initial Phase

In the initial phase the wayfinder has the lead role and talks to the route service. According to Klein (1982, p. 168), the initial phase consists of three subtasks for the wayfinder:

- getting into contact with the informant;
- making clear what he wants;
- succeeding in getting the informant to take over the task of giving him route directions.

Neither Klein nor Wunderlich and Reinelt (p. 183) went on to study the initial phase in detail. However, we identify the three subtasks:

- A cognitive task. The wayfinder has to find a proper specification for his route request, which means a specification that is sufficient for the informant in the given communication context. The informant has to activate a spatial cognitive representation and to identify the specification of the wayfinder in this representation.
- An interactional task. The wayfinder has to manage the three subtasks of the initial phase identified above. The informant has to pay attention, listen, and respond by confirming that the specification of the route was received and sufficient.
- A linguistic task. Wayfinder and informant interact via sign systems (a language), and all three subtasks of the initial phase have to be expressed in a sign system and understood by the recipient. The wayfinder has to contact the informant via language, express the request in a language, and be ensured via language that the informant took over.

Technically, the three subtasks of the initial phase are dependent on the architecture and interface of the navigation services. Consider for example the web-based navigation service of Figure 1. The communication with a web-based service is performed via the HTTP protocol. Getting into contact is realized by typing a uniform resource identifier in a web browser's address field (realizing an HTTP get request), or alternatively by following hyperlinks to a service (also realizing an HTTP get request). Making clear what the wayfinder wants is dictated by the services' interface. Succeeding in getting the route service to take over is realized by pressing the *Search* button (realizing another HTTP get request, parameterized by form data), and can prolong if there are ambiguities in the request to be resolved.

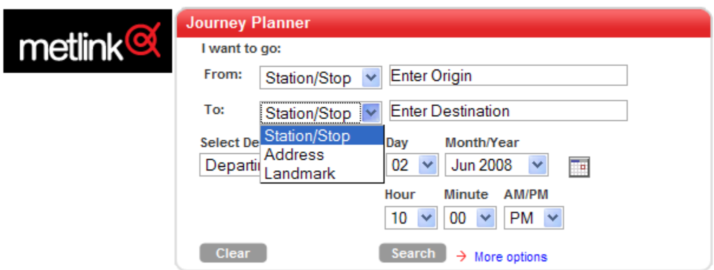


**Fig. 1.** The initial phase of wayfinding communication with a typical web-based navigation service: Melbourne's Metlink (public transport) Journey Planner (snapshot from June 2008).

### 3.2 The Center Phase

The phase of giving route directions is initiated and terminated by the informant (Wunderlich and Reinelt, 1982, p. 187). In this phase again we can identify:

- A cognitive task. The informant—e.g., the navigation service—has to interpret correctly the specification of a route request by the wayfinder.
- An interactional task. The informant has to plan a route according to the specification.
- A linguistic task. The informant has to express the route in a comprehensible manner, verbally and/or graphically.

Figure 2 shows route descriptions of the web-based navigation services listed in Figure 1.


**Fig. 2.** Route directions given by Metlink Journey Planner, upon a request for a trip from the University / Royal Parade (a stop name) to Flinders Street Railway Station (a stop name) departing earliest at 10:50am on 27 July 2008.

### 3.3 The Securing Phase

Wunderlich and Reinelt (1982) report a large variety of communication patterns in the securing phase between people. They can consist for example of summaries, repeats, paraphrases, more detailed descriptions of crucial parts, additional information for the decisions points along the route, or a discussion of alternatives. Corresponding to this diversity we identify a variety of cognitive, interactional and linguistic tasks, some of them assigned to the wayfinder, some to the informant. However, they basically repeat the initial and center phase: expression of a question, understanding, acting on a response (e.g., modify, generalize or precisify the plan), conveying the response.

Aspects of a securing phase are present in Figure 2. A wayfinder can click on the hyperlinks in the verbal route descriptions to get more information on the stops, and also stop maps and leg timetables can be requested. Further buttons provide options for re-enquiry (*Modify*, *Search* *again*, *Return journey* and *Onward journey*). The securing phase is terminated as soon as the wayfinder initiates the closing phase.

### 3.4 The Closing Phase

As Wunderlich and Reinelt (1982, p. 188) remark, “only [the wayfinder] can state that the request has been satisfactorily fulfilled”. A typical initiation of the closing phase is an expression of gratitude, and termination is made by turning away. In this phase we can identify:

- A cognitive task. The wayfinder determines that he is satisfied with the given information.
- An interactional task. While the wayfinder’s attention moves to realize the given information, the informant can deactivate his cognitive map and return to conventional communication or other tasks.
- A linguistic task. The wayfinder should indicate that he is satisfied.

Our example of a web-based navigation service gives the wayfinder the opportunity for giving feedback, as an expression of gratitude, and for printing the directions (also indicating satisfaction). Further a wayfinder can follow some links to external webpages, or he can simply close the web client and turn away from the machine, be it a mobile device, a terminal, or a desktop computer.

## 4 The Spatiotemporal Context of Wayfinding Communication

Communication with a navigation service takes place in a spatiotemporal context. To capture and categorize this context let us refer to Janelle (2004), who studied spatial and temporal communication constraints between communication partners given the diverse range of communication channels. His categories concern (see also Table 1):

- location of the communicators: *physical co-presence* or *telepresence*
- time of the communication: *synchronous* or *asynchronous*

**Table 1.** Janelle’s spatial and temporal communication constraints (2004) applied on seeking route advice.

| | *synchronous* | *asynchronous* |
|---|---|---|
| *physical co-presence* | e.g., face-to-face, or from mobile location-aware device | e.g., from you-are-here maps, or departure plans at bus stops |
| *telepresence* | e.g., via telephone or from web service | e.g., departure plan from a web page |

Compared to Janelle's two dimensions for a general communication context, a wayfinding communication is coming with two other context dimensions (called indexes or deixis in pragmatics, see Suchman 1987):

- location of departure: *from here* or *from elsewhere*
- time of departure: *now* or *in future*

With this categorization at hand, one can distinguish the communication context for different navigation services. For example, services on mobile devices—such as location-based services, car navigation services, or tourist guides—establish a context characterized by the quadruple {*physical co-presence*, *synchronous communication*, *from here*, *now*}. They can infer the meaning of from here by mobile positioning. In comparison, services provided on the web for in-advance trip planning establish a context characterized by the quadruple {*telepresence*, (quasi-) *synchronous communication*, *from anywhere*, *anytime*}. Especially web-based navigation services have no clue to distinguish between wayfinders seeking advice for immediate departure from their current location and wayfinders seeking advice from elsewhere and in future. Nevertheless, web-based navigation services typically pre-fill the departure time with the actual time as a default (Fig. 1). They do not yet use IP localization or other positioning technologies to pre-fill the departure location.

## 5 Representing an Intelligent Agent in Wayfinding Communication

A service has to understand a person's wayfinding request and has to respond as another person would do. This was called intelligent communication behavior. For artificial intelligence Brooks (1991) has identified three characteristics of an intelligent agent: being able to cope with situatedness, embodiment and emergence. To be precise, Brooks lists a fourth property, intelligence. For him, intelligence shows in the complexity of behavior "determined by the dynamics of interaction with the world" (p. 584). In the present paper, however, the intelligent agent—the navigation service—is not itself physically autonomous in the world, but communicates to an agent that is situated, embodied and capable to cope with emergence: the wayfinder. Furthermore, the service is supposed to communicate like a person, who has all these abilities. Accordingly, in our case intelligence does not appear in the complexity of any physical behavior of the service, but in the complexity of its communication behavior. This means the service requires an awareness of situatedness, embodiment and emergence to be able to give route advice like a person. This argument is still in line with Brooks's (1991) argument for a bottom-up emergence of intelligent behavior. It is also in line with current human computer interaction paradigms. For example, Dourish (2001)—"dialog is central to our notion of interaction with the computer" (p. 10)—identifies embodiment as the common ground and challenge for human computer interaction (p. 22).

Hence, an intelligent navigation service's communication behavior should be:

- Situated. It should be aware of the context of the communication situation. Beyond the spatiotemporal context discussed above (Section 4), this includes an awareness of the environment of the current location of the wayfinder, and what it offers and affords. Our example (Figures 1 and 2) is poor of situatedness except the pre-fill of departure time.
- Embodied. It should be aware of the human capabilities to move in an environment, and their commonsense, or naive understanding of the world (Egenhofer and Mark 1995). The particular person and its abilities and preferences can be taken into account. With respect to content of advice, this concerns concepts of mobility such as comfort or convenience, costs, risk or trust. And with respect to language, this concerns proficiency in relative, qualitative and egocentric spatial concepts. Our example (Figures 1 and 2) is tuned for public transport users, but not flexible enough to adapt to other means of transport or more specialized individual requirements.
- Aware of emergence. It should be aware of the coherent cognitive structures of the wayfinder that have evolved during the process of learning spatial environments. This concerns their procedural and declarative spatial knowledge, in particular the hierarchic organization of spatial cognitive representations. Our example (Figures 1 and 2) does not show any consideration of previous knowledge of the wayfinder, but it has a hierarchic approach of releasing more details on request.

## 6 Conclusions

This paper suggests a criterion for intelligent navigation services. This criterion forms a vision and also a benchmark for the directions of further technological developments in this area. The suggested criterion is a Turing test of limited scope and tenor. It is restricted to the domain of giving route advice, and also limited to a natural wayfinding discourse, i.e., reasonable, goal-oriented utterances of the wayfinder. In accordance with the original Turing test, the communication channel may still be teletype (text, such as in web forms for the wayfinder, and in verbal descriptions by the web service), but a variety of other channels exists as well, such as speech, graphical interfaces, and visual interfaces to cope with facial expressions and gestures. A navigation service will pass this test if it behaves in its spatial communication like a person.

This criterion is then used to study the desired characteristics of an intelligent navigation service. The characteristics are derived combining three independent approaches to study the wayfinding communication process: the phases of wayfinding communication, the spatiotemporal context of wayfinding communication, and the characteristics of an intelligent autonomous agent. Since these approaches are sufficiently orthogonal they can be crossed. Figure 3 illustrates this for two of the three approaches, communication phases (and subtasks; Section 3) and awareness (Section 5); spatiotemporal context (Section 4) forms the fourth dimension.

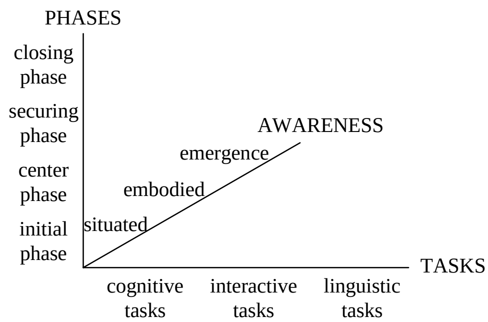


**Fig. 3.** The framework built by the phases of wayfinding communication with their individual subtasks, crossed with the properties of an intelligent agent. Missing in this graph: the spatiotemporal context, forming a fourth dimension.

From the discussion in Section 2 we can conclude that any framework is insufficient to facilitate designing a service guaranteed to pass the test to be called intelligent. Nevertheless, in our framework we could find reasons for each approach to be included in a benchmark, among them their orthogonality. The four dimensions of this framework have shown to be useful already in a preliminary investigation of the initial phase of the communication process identifying requirements and needs for further research (Winter and Wu 2008).

In the future the framework can be used to study systematically the structure of existing knowledge, gaps of knowledge, and requirements for research. Also existing navigation services can be investigated by this way.

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## References

Agrawala, M.; Stolte, C., 2001: Rendering Effective Route Maps: Improving Usability Through Generalization, SIGGRAPH 2001. ACM, Los Angeles, CA, pp. 241-250.

Allen, G.L., 1997: From Knowledge to Words to Wayfinding: Issues in the Production and Comprehension of Route Directions. In: Hirtle, S.C.; Frank, A.U. (Eds.), Spatial Information Theory: A Theoretical Basis for GIS. Lecture Notes in Computer Science, 1329. Springer, Berlin, pp. 363-372.

Brooks, R.A., 1991: Intelligence Without Reason. In: Myopoulos, J.; Reiter, R. (Eds.), 12th International Joint Conference on Artificial Intelligence IJCAI-91. Morgan Kaufmann Publishers, San Mateo, CA, pp. 569--595.

Cassell, J.; Kopp, S.; Tepper, P.A.; Ferriman, K.; Striegnitz, K., 2007: Trading Spaces: How Humans and Humanoids Use Speech and Gesture to Give Directions. In: Nishida, T. (Ed.), Conversational Informatics. Wiley Series in Agent Technology, John Wiley & Sons Ltd., Chichester, UK, pp. 133-160.

Crockett, L.J., 1994: The Turing Test and the Frame Problem: AI's Mistaken Understanding of Intelligence. Ablex Series in Artificial Intelligence. Ablex Publishing Corporation, Norwood, NJ, 216 pp.

Dale, R.; Geldof, S.; Prost, J.-P., 2005: Using Natural Language Generation in Automatic Route Description. Journal of Research and Practice in Information Technology, 37 (1): 89-105.

Denis, M., 1997: The Description of Routes: A Cognitive Approach to the Production of Spatial Discourse. Current Psychology of Cognition, 16 (4): 409-458.

Dourish, P., 2001: Where the Action Is: The Foundations of Embodied Interaction. The MIT Press, Cambridge, Mass., 233 pp.

Egenhofer, M.J., 1997: Query Processing in Spatial-Query-by-Sketch. Journal of Visual Languages and Computing, 8 (4): 403-424.

Egenhofer, M.J.; Mark, D.M., 1995: Naive Geography. In: Frank, A.U.; Kuhn, W. (Eds.), Spatial Information Theory. Lecture Notes in Computer Science, 988. Springer, Berlin, pp. 1-15.

French, R.M., 2000: The Turing Test: The First Fifty Years. Trends in Cognitive Sciences, 4 (3): 115-121.

Gigerenzer, G., 2007: Gut Feelings: The Intelligence of the Unconscious. Viking Penguin, New York, NY.

Golledge, R.G., 1999: Human Wayfinding and Cognitive Maps. In: Golledge, R.G. (Ed.), Wayfinding Behavior, The Johns Hopkins University Press, Baltimore, MA, pp. 5-45.

Janelle, D.G., 2004: Impact of Information Technologies. In: Hanson, S.; Giuliano, G. (Eds.), The Geography of Urban Transportation, Guilford Press, New York, pp. 86-112.

Klein, W., 1979: Wegauskünfte. Zeitschrift für Literaturwissenschaft und Linguistik, 33: 9-57.

Klein, W., 1982: Local Deixis in Route Directions. In: Jarvella, R.J.; Klein, W. (Eds.), Speech, Place, and Action, John Wiley & Sons, Chichester, pp. 161-182.

Kopp, S.; Wachsmuth, I., 2004: Synthesizing Multimodal Utterances for Conversational Agents. Computer Animation and Virtual Worlds, 15 (1): 39-52.

McCarthy, J.; Hayes, P.J., 1969: Some Philosophical Problems from the Standpoint of Artificial Intelligence. In: Melzer, B.; Michie, D. (Eds.), Machine Intelligence, Edinburgh University Press, Edinburgh, pp. 463-502.

Pontikakis, E., 2006: Wayfinding in GIS: Formalizing the Basic Needs of a Passenger When Using Public Transportation. PhD thesis, Institute for Geoinformation and Cartography, Technical University Vienna, Austria.

Pylyshyn, Z.W. (Ed.), 1987: The Robot's Dilemma: The Frame Problem in Artificial Intelligence. Theoretical Issues in Cognitive Science. Ablex Publishing, Norwood, NJ, 156 pp.

Richter, K.-F., 2008: Context-Specific Route Directions. Monograph Series of the Transregional Collaborative Research Center SFB/TR8, 3. Akademische Verlagsgesellschaft, Berlin.

Roth, W.-M., 2007: From Action to Discourse: The Bridging Function of Gestures. Cognitive Systems Research, 3 (3): 535-554.

Searle, J.R., 1980: Minds, Brains, and Programs. The Behavioral and Brain Sciences, 3: 417-424.

Stevens, A.; Coupe, P., 1978: Distortions in Judged Spatial Relations. Cognitive Psychology, 10 (4): 422-437.

Suchman, L.A., 1987: Plans and Situated Actions: The Problem of Human Machine Communication. Cambridge University Press, Cambridge, UK, 203 pp.

Timpf, S., 2002: Ontologies of Wayfinding: A Traveler's Perspective. Networks and Spatial Economics, 2 (1): 9-33.

Turing, A.M., 1950: Computing Machinery and Intelligence. Mind, 59 (236): 433-460.

Winter, S.; Wu, Y., 2008: Towards a Conceptual Model of Talking to a Route Planner. In: Bertolotto, M.; Ray, C.; Li, X. (Eds.), W2GIS 2008. Lecture Notes in Computer Science, 5373. Springer, Berlin, pp. 107-123.

Wunderlich, D.; Reinelt, R., 1982: How to Get There From Here. In: Jarvella, R.J.; Klein, W. (Eds.), Speech, Place, and Action, John Wiley & Sons, Chichester, pp. 183-201.