A Knowledge Elicitation Study for a Speech Enabled GIS to Handle Vagueness in Communication

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Abstract. One of challenges toward development of usable speech enabled Geographical Information Systems (GIS) is how to handle vagueness that naturally exist in human-GIS communication. The meaning of some spatial concepts are not only fuzzy, but also context dependent. To enable the GIS to handle the vagueness problem, in particular, the context-dependency sub-problem, we propose to design a collaborative speech enabled GIS, which can emulate a human GIS operator's role and handle the vagueness problem in communication through collaborative dialogues. To emulate a human GIS operator's role, the GIS must have knowledge corresponding to a human GIS operator's knowledge involved in handling the vagueness problem. This paper describes a knowledge elicitation study that we conducted to elicit human GIS operators' knowledge about how to handle the vagueness problem through collaborative dialogues. A speech enabled GIS, Dave_G, incorporates part of the study results. This system is able to handle the vagueness problem through various collaborative dialogues.

Keywords: GIS, Knowledge elicitation study, Vagueness problems, Human-GIS Communication, Collaborative dialogue strategies.

1 Introduction

Geographic Information Systems (GIS) are computer systems for capturing, storing, querying, analyzing, and displaying geographically referenced data [1], such as map layers of various spatial features (e. g. land parcels, roads, lakes, cities etc.). They have been broadly applied in various fields that use spatial data since the 1960s, for instance, natural resource management and assessment, criminal incident analysis, crisis management, automobile GPS, web-based map systems, etc.

To improve the system usability and support broader use of the system, the GIS community has spent much effort on designing transparent interfaces. One line of the efforts is to develop natural interfaces, e. g. speech and gesture enabled interfaces, to GIS [2-6]. There have been some experimental natural interfaces for geographic information use, such as “*Put-that-There*” [7], CUBISON [8], *QuickSet* [9-11], *Sketch and Talk* [12], *iMap* [13], and *Dave_G* [14].

Most of the existing experimental systems use speech as one of interaction modalities in communication with the user. To develop a usable speech enabled GIS, one of

the challenges that must be addressed is how to semantically interpret a speech request involving spatial concepts. The user's natural language requests can be incomplete, ambiguous, vague, and inconsistent [15-18]. The meaning of a vague linguist term representing a spatial concept is fuzzy, that is, its meaning does not have a clear boundary. Its meaning is also context dependent, that is, its meaning is different in different contexts. This study focuses on handling the vagueness problem in human-GIS natural language communication, in particular, the context-dependency sub-problem.

Human communicators can usually successfully communicate vague spatial concepts with each other through collaborative dialogues. For example, in an Emergency Operation Center for the hurricane crisis management in Florida, a crisis manager who does not know to operate GIS can collaborate with an expert GIS operator and can still get desired spatial information from the GIS although their natural language communication may involve vagueness. Success in collaborative human-human communication drives us to design a speech enabled GIS which can handle the vagueness problem by emulating a human GIS operator's role. The goal of this study is to collect human knowledge about how human communicators, in particular, human expert GIS operators, understand the meaning of a vague spatial concept in different contexts and reduce vagueness in communication through collaborative dialogues.

Knowledge elicitation is the process of collecting information that is thought to be relevant to desired knowledge from a human resource of knowledge [19]. There are various types of knowledge elicitation techniques [20-23]. The observations and interviews are often used for early stage of system design, such as, conceptualizing the problem domain. They are direct methods of watching experts and talking to them. In this study, we took these two techniques to collect human communicators' knowledge involved in handling vagueness in communication. This paper describes design, the data collection process, and preliminary findings of the knowledge elicitation study.

2 Research Design

Our research questions in the knowledge elicitation study are:

- 1) How do human communicators understand the meaning of a vague spatial concept in communication?
- 2) What kinds of collaborative dialogue strategies can be used by human communicators to reduce vagueness in communication of spatial concepts?
- 3) How does the human GIS operator reason when the user speaker's request involves a vague spatial concept?

The first knowledge elicitation technique that we planned to use is participant observation. We planned to invite pairs of GIS experts and non-expert GIS users to work together on a set of tasks (see Table 1) that involve communication of a vague spatial concept, *near*, and use of GIS commands. Through observing their collaboration process, we expected to answer the research question 2 and observe the communication between pairs of human communicators, in particular, collaborative dialogue strategies used to reduce vagueness in communication.

The eight tasks are about getting a map near a reference location. The maps are required to fit for different contexts (Table 1). They have some contextual factors in common, such as the goal, time frequency/period and bigger spatial contexts, also have different contextual factors, such as transportation mode and reference locations.

Table 1. Eight Tasks in Participant Observation

Task No.	Task Content	Common Contextual Information	Different Contextual Information	
			Transportation mode	Reference location
1	Show a map showing grocery stores <i>near</i> a home location.	Goal: food shopping;	By driving a car	Apartment A
2		Time: Weekly;	by walk	Apartment A
3		Space: In a big city like New York	By driving a car	Apartment B
4			by walk	Apartment B
5	Show a map showing cities <i>near</i> a home city.	Goal: Vacation;	By driving a car	City A
6		Time: two day weekend	By air	City A
7			By driving a car	City B
8			By air	City B

Near is a typical example used to illustrate the vagueness problem in communication of spatial concepts [15, 24-27]. We expected that using this concept in the tasks would lead to vagueness in communications between each pair of participants. We hoped that the vagueness problem would further stimulate the participants to use collaborative dialogues.

The second knowledge elicitation technique is interview. We also planned to interview the participants after the observation and expected to answer the research question 3 by collecting data about the human GIS operators’ reasoning process underlying their collaborative communication with users during the observation process. We also expected to answer the question 2 about their different understandings of the same vague spatial concept in different communication contexts.

3 Data Collection

Four pairs of GIS expert operator participants and non-expert user participants participated in our study. They were all university staff or graduate students. All of them spoke in English fluently. This section details the entire knowledge elicitation data collection process.

3.1 Introduction Session

After a pair of GIS expert operator participant and non-expert user participant came to our experiment location (a computer lab), we first distributed consent forms to them and collected the forms back when they were done with reading and signing the forms.

Consequently, to the user participant, we introduced basic concepts of GIS, such as its definition, major functions and applications. We also explained the eight tasks (Table 1) to be completed later with the GIS expert participant together. We required the user participant to keep the context specified for each task in mind and express each request as naturally as possible to the operator participant.

Finally, to the operator participant, we demonstrated major GIS functions, in particular, those that would be used to complete the required tasks. The demonstration was on a laptop to be used by the operator later to help the user participant. It was installed with GIS software, ArcView 3.1. We also required the operator participant to practice using the laptop and the GIS software, in particular, those major GIS functions.

3.2 Observation Session

The pair of participants started to work on the eight tasks together after the introduction session. The user participant read requirements for each of the eight tasks at first, and then talked to the operator participant for each request. The operator participant helped the user participant to generate a map for each task. They often had several round of collaborative dialogues for most of the tasks.

When the pair of participants collaborated with each other on these tasks, we recorded the entire collaboration process via a video camcorder. The researcher focused on observing and taking written notes on their collaborative dialogue strategies and major their facial expressions, in particular, when they stopped talking or working and were hesitating for something. Those collaborative dialogue strategies used and stopping would lead to questions and discussion in the later interview.

3.3 Interview Session

We interviewed the participants right after the observation session so that they would still remember what happened in the observation session and what they had thought in order to handle the vagueness problem. The interview process was recorded as digital audio data and written notes.

At first, we gave a short interview to the user participant. The participant was asked with questions about how they understood the meaning of the vague spatial concept near in the tasks 1 to 4 and how they did in the group of tasks 5 -8. We also asked the participant to list all possible collaborative dialogue strategies that he/she thought could help to handle the vagueness problem and order them.

We interviewed the operator participant consequently. In addition to the questions asked for the user participant, the questions to the operator participant focused on his/her reasoning process involved in handling the vagueness problem. We asked the reason why some collaborative dialogue strategies was used in some of the tasks and

the participant's mental belief on the parameter that was instantiated by the vague spatial concept *near* and the execution result of GIS commands that used the parameter value instantiated from *near*. We also asked why they stopped working or hesitated for a while during the observation session if they did so.

4 Findings

The data that we collected all are qualitative. So, we take an interpretative reading method to read and analyze the data collected. This section summarizes the findings from our data analysis.

4.1 Understanding of a Vague Spatial Concept

The meaning of a vague spatial concept is understood in a context where the map is used. For example, the GIS operator participants understood the meaning of the vague spatial concept *near* in communication by imaging the situation that the requested map was used for. One operator participant showed a map of grocery stores that he thought were near to the user after receiving the request from the user. He explained how he estimated near during the operation in the interview. He was thinking how he was going to shop, such as driving a car from the specified apartment to those grocery stores. Then, he assumed that this was the user's reason to ask for the map.

4.2 Collaborative Dialogue Strategies

We find five major collaborative dialog strategies that the GIS operator can take to handle the vagueness problem:

- Strategy 1: The GIS operator shows a map result with a parameter value estimated from a vague spatial concept, and then asks the user for comments on the map result;
- Strategy 2: The operator directly tells the user an estimated meaning of the vague spatial concept by the operator and asks the user for feedback on the estimated meaning directly;
- Strategy 3: The GIS operator asks the user for some major contextual factors that influence the meaning of the vague spatial concept to have a better understanding of the concept;
- Strategy 4: The GIS operator directly asks the user for the meaning of the vague spatial concept that the user intends and then uses it in the GIS operation;
- Strategy 5: The GIS operator asks the user for modifying comments on an existing estimated meaning of a vague spatial concept.

4.3 Reasoning Process

When the GIS operator receives the request involving a vague spatial concept, he/she needs to make a decision about what to do next, e. g. taking one of the five collaborative dialogue strategies described above. The recognition-primed decision (RPD)

model [28, 29] explains human's decision making process. To explain the GIS operator's decision-making process involved in handling the vagueness problem, we analyze our interview data and summarize major features of a computational RPD model that describes the GIS operator's decision making process. The results are given in Table 2.

Table 2. Major Features of a Computational RPD Model

Key Cues (to identify the problem)		Goals	Expectancies	Course of Actions
Common	Different			
The user utterance is clear; There is a GIS command available for the request; A spatial concept expressed in the user's utterance is vague; The user has not provided an exact meaning of the vague concept.	Some contextual information is provided by the user or assumed by the operator. The operator has knowledge about how to estimate a meaning of the vague spatial concept based on context information.	Instantiate a para in the GIS command from the vague concept	The user is able to provide comments on the estimated meaning of the vague spatial concept shown on the map	Strategy 1
			The user is able to provide comments on the explicitly expressed estimated meaning of the vague spatial concept.	Strategy 2
	Part of major context information has not been shared by the user.		The user is able to provide such context information.	Strategy 3
			The user is able to provide an exact meaning of the vague spatial concept.	Strategy 4
	An existing estimated meaning of the vague spatial concept has been provided to the user.		The user is able to provide modifying comments on the existing estimated meaning of the vague spatial concept.	Strategy 5

5 Conclusion

This paper describes a knowledge elicitation study that we conducted to help a speech enabled GIS to handle the vagueness problem in human-GIS communication. The preliminary findings about how human communicators understand the meaning of a vague spatial concept in communication help us to better understand the vagueness problem in human-GIS communication and how the GIS can understand the meaning

of a vague spatial concept in the communication context. The findings about various collaborative dialogue strategies and the human GIS operator's decision-making process help us to design intelligent speech enabled GIS which can handle the vagueness problem through collaborative dialogues. These findings are also useful for design of other speech enabled information systems to handle vagueness in human-computer communication.

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