A Knowledge Elicitation Study for Collaborative Dialogue Strategies Used to Handle Uncertainties in Speech Communication While Using GIS

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Abstract. Existing speech enabled Geographical Information Systems (GIS) needs to have capabilities to handle uncertainties that are inherent in natural language communication. The system must have an appropriate knowledge base to hold such capabilities so that it can effectively handle various uncertainty problems in speech communication. The goal of this study is to collect knowledge about how humans use collaborative dialogues to solve various uncertainty problems while using GIS. This paper describes a knowledge elicitation study that we designed and conducted toward this goal. The knowledge collected can be used to develop the knowledge base of a speech enabled GIS or other speech based information systems.

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

1 Introduction

Geographic Information Systems (GIS) are computer based mapping systems [1]. Since its early stage in the 1960s, they have been applied in various fields that use spatial data. Natural interfaces, e. g. speech and gesture enabled interfaces, have been proposed for GIS[2-6] over the years in order to further reduce the amount of training effort required from the GIS user. Some experimental GIS with natural interfaces have been developed. Early systems could accept only simple speech sentences which consisted of a few key words (such as CUBISON [7] and "Put-that-There" [8]) and/or simulated gestures (such as "Put-that-There" [8]). Along with advances in speech and gesture recognition in the computer technology field, some experimental natural interface-based GIS have been developed to accept more complicated speech input and/or pen-based gesture, such as QuickSet [9-11] and Sketch and Talk [12]. The most recent natural interface-based GIS can even recognize free-hand gesture, such as Dave_G [13].

Speech is used in most of the natural interfaces developed for GIS, and it is well known that natural language is not as precise as computer commands. The user's speech requests can contain various uncertainties. They can be incomplete, ambiguous,

M. Kurosu (Ed.): Human-Computer Interaction, Part IV, HCII 2013, LNCS 8007, pp. 135–144, 2013.

vague, and inconsistent [14-17]. Most of the existing speech enabled GIS do not handle such uncertainties well. They usually give a best guess only to the uncertain part in the user's speech request.

Human can usually successfully communicate with each other through collaborative dialogues, although their speech conversation also often contains various uncertainties. The success in human-human collaborative dialogues leads us to propose collaborative dialogues for speech enabled GIS to handle various uncertainty problems. The goal of this study is to collect human knowledge about how human communicators (human expert GIS operators in particular) handle various uncertainty problems in speech communication through collaborative dialogues.

To collect human knowledge, we need to apply some knowledge elicitation methods [18]. The observations and interviews are two of commonly used knowledge elicitation techniques [18-22]. They are direct methods of watching experts and interacting with them. In this study, we took these two techniques to collect human communicators' knowledge involved in handling various uncertainty problems while using GIS.

The first author's previous work also used these techniques on knowledge elicitation study for handling various uncertainty problems [23, 24]. However, the participant tasks designed in that study [23, 24] mainly focused on handling the vagueness problem. Each of these tasks involved speech communication of a vague spatial concept, *near*. The variety of uncertainty problems and their corresponding collaborative dialogue strategies that were discovered from that study were limited. The tasks designed for the participants to work on during the observation period in this study focused on various problems, instead of specifically on the vagueness problem.

2 Research Design

The research questions in the study include: (1) What kinds of uncertainty problems can occur in speech communication of spatial information requests while using GIS? (2) What collaborative dialogue strategies do human GIS operators take to handle these uncertainty problems? (3) How does a human GIS operator reason and make a decision during the process of communicating with the user, in particular, when the communication involves uncertainties?

2.1 Design of Participant Observation

The first technique used to collect human knowledge in this study is the 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). We would observe their collaborative dialogues to reduce uncertainties in the communication, which would answer the research question 1 and 2.

Table 1. Eight User Tasks in Participant Observation

Task No.	Task Content	Common Contextual Information
1	*Get a Florida map* (At first, you want to see a map of Florida with basic information at first, such as state boundary, county boundary, cities, major roads etc.)	**Traveling to Florida for Vacation**: Imagine that you are planning to have a 2 months of vacation over Florida and not familiar with Florida. You have several requests.
2	*Get a map of flooded area in Florida* (imaging that you want to know the areas that usually flood during the summer)	
3	*Get an Ohio map* (Imagine that you want to know where is the Ohio county in Kentucky).	**Living in Kentucky**: Imagine that you are living in Northern Kentucky Area (here, in this study, it means the Kenton County and Campbell county). You have several requests.
4	*Get a map of Northern Kentucky Area* (imagine that you want to get a map showing basic information, such as county boundary, cities, roads etc).	
5	*Get a map of rivers in Northern Kentucky Area* (suppose that you are interested in only major rivers, not all streams).	
6	*Get a map showing 50-ft buffer zones around all rivers in Northern Kentucky Area.* (Suppose that you are interested in buffer zones around major rivers).	
7	*Get a map showing all daycares in Northern Kentucky area near your home* (Imagine that you have a child and need to select a daycare near your home (and work location if you work. If you work, suppose that your home and work location are close and can be considered as one destination.)	
8	*Get a map showing all KY cities near your "home city" Lexington* (imagine you are looking for jobs around home city)	

There are two sets of tasks (Table 1) for each pair of user participants to complete during the participant observation. The first set of tasks was situated in the context of planning for traveling to Florida for a two-month vacation. Task 1 was intended to have them communicate missing information in the user request or on the map result because they may have different understandings on what should be displayed on the map. Task 2 involves communication of a general concept, the "flooded area", which can refer to flooded area at different levels. We expect that this task would drive the participants to use collaborative dialogues to handle the generality problem.

The second set of tasks was set in the context of living in Kentucky. Task 3 was designed for the ambiguity problem because the word "Ohio" in the northern Kentucky area may mean two different things, the state, Ohio, and the county in Kentucky, Ohio. Task 4 had the same purpose as Task 1. Task 5 and Task 6 were also designed for the generality problem because the term "rivers" can refer to major rivers or all streams. Task 7 and Task 8 were both designed for the vagueness problem and involved communication of a vague spatial concept, near.. The vagueness problem is more complicated than the other types of uncertainty problems because it involves both context-dependency and fuzziness problems. However, the first author of this paper had conducted a knowledge elicitation study that specifically focused on the vagueness problem before [25]. Therefore, we did not design so many tasks to cover the various situations that the vagueness problem can occur.

2.2 Design of Follow-Up Interview

We planned to interview the participants after the observation. Each pair of participants would have some common questions related to the uncertainties observed in the participant observation. The common questions focused on the uncertainty problems that were observed during the participant observation in this study or previous studies [23, 24]. If a type of uncertainty problems happened in the participant observation, we would summarize how it is handled in the observation, and then ask the participant what other strategies can be applied. If it does not happen, we would explain the problem definition at first, and then ask the participant what strategies he/she would take if it happened. This part of interview was designed to collect more data for the research question 1 and 2. It would also be helpful to answer part of the question 3, such as how to identify each type of uncertainty problems.

The GIS operator participants would have additional questions, which were focused on their reasoning process underlying their collaborative communication with users during the observation. We would ask them to use one of the examples that happened in the observation process to explain how they made the decision of taking one of collaborative strategies available in their mind to handle the uncertainty problems. This part of interview was designed to collect data for the research question 3.

3 Data Collection

The data collection for the knowledge elicitation study was conducted at the first author's office at Northern Kentucky University in summer 2011. The laptop at her office was installed with GIS software, ArcGIS Map 9.3, and some software for screen video recording and audio recording for the study. Four pairs of GIS operator and user participants participated in the study. All of the GIS operators were the first author's students in her past GIS classes at Northern Kentucky University. They were either college students or had already had full time GIS jobs. The user participants were students at Northern Kentucky University from different majors. Seven of them were native English speakers. One of them was a foreign student and spoke in English fluently.

Same as the first author's previous knowledge elicitation studies [23-25], the data collection process consisted of three sessions: introduction session, participant observation session, and interview session. This section details the process.

3.1 Introduction Session

The consent forms were distributed and collected at first after the participants came to the experiment location. They were also asked to fill out a brief questionnaire about their background, including their gender, age, education major, GIS software use experiences etc.

Next, we gave a brief introduction of the study to each participant. We explained basic GIS concepts and the eight tasks (Table 1) to the user participant. The eight tasks would be completed by using some GIS functions. So, we demonstrated these functions to the GIS operator participant at first, and then asked the operator participant to practice using these GIS functions.

3.2 Observation Session

Each pair of participants started to collaborate on each of the eight tasks after they finished the introduction work. The entire collaboration process was recorded via two video cameras and screen recording software (Figure 1) while the investigators observed their collaboration.

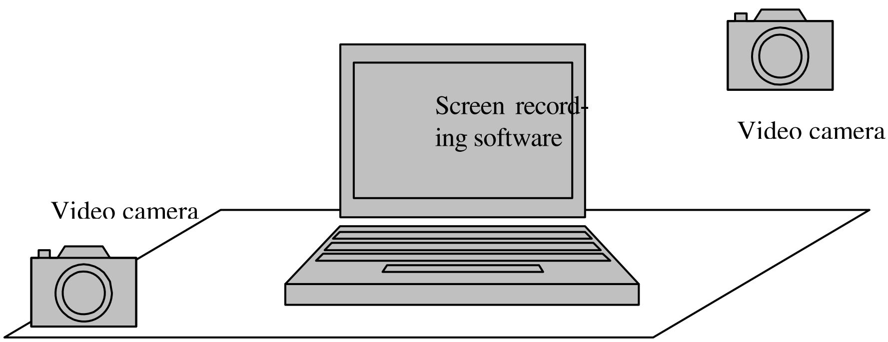

Fig. 1. Data Collection Setting for Participant Observation

The user participant initiated conversation with the operator participant for each task. The operator participant usually generated a map response for the user participant for each task. They usually need to use a few rounds of collaborative dialogues to complete each task.

3.3 Interview Session

The interview took place right after each pair of participants completed their tasks. The interview process was also recorded via multiple devices simultaneously (Figure 2). The investigators took written notes while interviewing the participant. Digital audio recording software on the computer and a digital video camera were also used to make sure that the interview process was recorded.

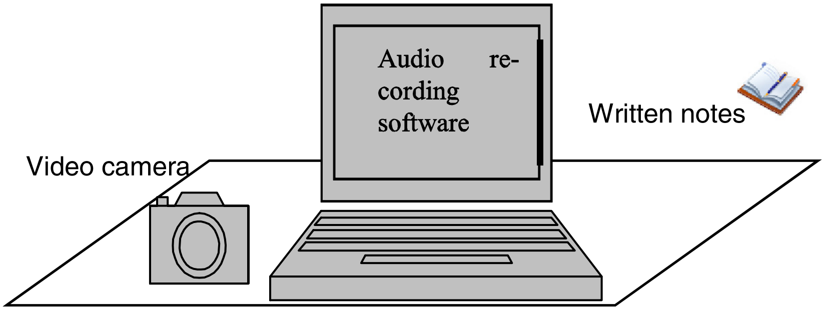

Fig. 2. Data Collection Setting for Interview

We conducted the interview by following the designed interview questions. The user participant was interviewed before the operator participant. This is because the questions for the user participant were less than those for the operator participant.

4 Findings

Due to the qualitative nature of the collected data, an interpretative reading method was applied to read and interpret all video, audio and written data. This yielded three major findings that correspond to the three research questions.

4.1 Uncertainty Problems

Several uncertainty problems were found in the speech communication while using GIS, including unclearness, forgetting details, incompleteness, vagueness, ambiguity, and generality. The first four types of uncertainty problems have already been discovered and explained in the first author's previous studies [23-25]. Therefore, we focus on explaining the last two types, that is, the ambiguity problem and the generality problem. Explanation to these two types of problems and some dialogue examples that were discovered from the participant observation are given in Table 2.

Table 2. Uncertainty Problems and Dialogue Examples

Type No.	Uncertainty Problem	Dialogue Example (O: GIS operator; U: User)
1	*Ambiguity:* Some terms in the user's speech request have two different meanings.	U: …Well can I get an Ohio map? O: An Ohio map? U: Mhmm, check and see the Ohio county that's in Kentucky. O: The Ohio county? The county in the state of Ohio? U: Umm no, the Ohio county that's in Kentucky.
2	*Generality*: A term in the user's request corresponds to different GIS datasets that provide different levels of details.	U: Since we're on Campbell county, can I see a map of the rivers around there? O: Okay. U: Well alright. And those are just the major rivers, right? O: Yes. U: No streams?

4.2 Collaborative Dialogue Strategies

The GIS operator usually has multiple collaborative strategies to handle each type of the uncertainty problems. Collaborative dialogue strategies for the ambiguity problem and the generality problem are given in Table 3.

Table 3. Collaborative Dialogue Strategies

Type No.	Uncertainty Problem	Collaborative dialogue strategies
1	Ambiguity	1. The GIS operator makes an assumption on the ambiguous part; 2. The GIS operator directly asks the user for clarification; 3. The user directly provides more context information to narrow down the options for the ambiguous part without being asked by the GIS operator
2	Generality	1. The GIS operator directly provides more detailed information at first and asks for clarification later; 2. The user assumes some context information, see the map results from the operator at first, and then clarifies the level of detailed information later if needed.

The results about collaborative dialogue strategies discovered in this study and previous studies [23-25] show that there are two common strategies for these various uncertainty problems. One common strategy, referred to as Strategy 1, is to show a map result to the user based on the operator's assumption about the uncertainty in the user's request and then to wait for the user's correction if needed. The other common strategy, referred to as Strategy 2, is to ask the user to clarify the uncertain part in the user's request and then generate a map response based on the user's response to the user.

4.3 Reasoning Process

The GIS operator's reasoning process usually includes a few major steps:1) Understanding the user request and interpreting it as the common goal of collaboration between the operator and the user; 2) Locating an appropriate GIS command for the user request; 3) Instantiating all parameters of the selected GIS command from the user request; 4) Executing the selected GIS command; 5) Returning responses to the user.

At step 3, uncertainty can arise if one of the parameters of a GIS command cannot be directly instantiated from the user's request. In this situation the operator must identify the uncertainty problem and make a decision about which collaborative dialogue strategy should be used to handle it. If the operator uses Strategy 1 and a parameter is instantiated based on the operator's assumption, the operator will need to wait for the user's correction feedback at Step 5. If the operator uses Strategy 2 and the uncertainty problem is asked to be clarified by the user, the operator returns a response to the user at Step 5 without uncertainties.

5 Conclusion

This paper describes the knowledge elicitation study that we conducted to help a speech enabled GIS to handle various uncertainty problems in human-GIS communication. The study results discovered two uncertainty problem types, ambiguity and generality, and their collaborative dialogue strategies, which are not shown in previous studies [23-25]. The paper also describes the preliminary findings about the operator's reasoning processing, in particular, about how to make a decision about what to do when the user's request contains some uncertainty.

These findings will be helpful for us to further improve our design of existing speech enabled GIS, in particular, design of the knowledge base and reasoning algorithms that are needed for the system to handle various uncertainties inherent in speech communication. These findings can also be extended for other speech based information systems.

Acknowledgments. This work is supported by Northern Kentucky University CINSAM grant (2011) and Northern Kentucky University's NSF Project FORCE summer UR-STEM Program (2011).

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