spacebook-project.eu

Summary of SpaceBook project results

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Umeå University	UMU
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Kungliga Tekniska Högskola	KTH
Liquid Media AB	LM
University of Cambridge	UCAM
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Copies of reports and other material can also be accessed via the project's administration homepage, http://www.spacebook-project.eu

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1 Executive Summary

The SPACEBOOK project has pioneered the use of speech-based dialogue to support pedestrian navigation and exploration of urban environments. While there have been many new approaches to this problem, ranging from Google glasses, to more routine multi-modal touch screens, to even haptic interfaces, to our knowledge SPACEBOOK is the first system to rely solely on natural language speech and text-to-speech responses to support real-time, in situ navigation and exploration of the urban environment. While there has been recent industrial interest in voice-based, mobile city information systems (e.g. Apple's Siri system), SPACEBOOK is unique in pioneering the modeling of the pedestrian's field of view to provide situated speech-based dialogue to support both navigation and exploration.

The primary hypothesis of the SPACEBOOK project is that such a speech-only interface is feasible and can be used reliably by a wide range of subjects. A secondary hypothesis is that such a set-up could also be rated as more enjoyable and informative than the alternatives. To test both of these hypotheses the SPACEBOOK team built a series of prototype systems which culminated in a single system that was tested with subjects on the streets of Edinburgh. The results of this evaluation (and others), lend support to our hypotheses that such systems can be made reliable and enjoyable. This suggests that the technology laying behind SPACEBOOK could and should be further developed and refined toward large scale development, deployment and use.

In addition to the overarching goal of confirming the value and promise of the SPACEBOOK vision, we have conducted research in a variety of sub-areas where the SPACEBOOK domain serves as a real-world task environment. The objectives, work performed and results in these focused sub-areas are touched on below.

2 Concept and Objectives

Imagine you are visiting an unknown European city. You arrive at the central train station toward night fall. Now you must find your hotel. You feel uncomfortable asking for directions from random people on the street. You are not so skilled at using maps, and in any case you don't want to be bothered looking down or having to read street signs as you navigate. You are lucky to have an Android phone with the SPACEBOOK app that speaks directions into you ear as you *navigate* your way to your hotel. With your eyes free and while pulling your suitcase, you listen as it guides the way – "OK continue another 100 meters, and turn right into the alleyway immediately after passing a Tesco on your right."

Now after a good night's sleep, you want to explore the city, learning about its history, attractions and other features. As you walk down the street from the hotel, a stunning neoclassical building on your left comes into view. Without pushing any buttons, you simply say "SpaceBook! What is the building on my left?". SPACEBOOK answers, "That is the National Art Museum. It houses ... (you listen for 20 seconds to the basic introduction)". Then you interrupt, "when does it close today?". SPACEBOOK answers, "It closes at 4 o'clock today." You continue walking. You have plenty of time (and now enhanced capability) to *explore* the city on foot.

Put simply, SPACEBOOK's core objective is to provide comfortable hands-free, eyes-free support for urban pedestrians exploring and acquiring knowledge of a city, by taking advantage of, and in some cases, extending the state-of-the-art in speech understanding, natural language processing, question-answering, natural language generation and text-to-speech technology. In addition SPACEBOOK provides a task environment in which more focused scientific and technical knowledge was generated. Specifically we advanced the state of the art in:

I. **Model-based approaches to plan generation and recognition.** There are essentially three approaches to building agents: 1.) they can be hand programmed; 2.) they can be learned from data; 3.) they can be *model-based*, arising from a first principles model of the agent's environment, goals, actions, sensors, etc. The model-based approach is characterized by very flexible behavior, but significant scalability challenges. The SPACEBOOK task environment is a real-world example that helps evaluate the merits of the model-based approach and drive algorithmic innovation in generation and recognition of behavior in the model-based approach. Model-based approach for plan generation is being used for dialogue management, while for plan recognition is being used for goal recognition. Both of these threads are implemented in two software modules developed in the project.

II. **Statistical learning techniques for interaction management.** The determination of when and in what sequence to execute actions in an uncertain, partially-observable environment is a longstanding topic in Artificial Intelligence. One branch of work focuses on using reinforcement learning over *partially observable Markov decision processes* (POMDPs) to decide on a policy that determines the correct action to execute based on the agent's belief state about the world. There are three key issues that complicate this problem: 1.) determining which features of the world should map into a limited set of state variables for the POMDP; 2.) building realistic simulations to feed reinforcement learning with sufficient data; 3.) algorithmic issues that enable POMDPs to scale to larger numbers of state variables and actions. SPACEBOOK provides a challenging task environment in which we tested reinforcement learning for POMDPs, where actions are the next communication action of the SPACEBOOK system.

III. **Machine learning of natural language understanding components.** An active research area lately has been the learning of natural language understanding components that map natural language (e.g. English) to logical expressions in a *meaning representation language* (MRL) that can drive applications (e.g. query a database, control a DVD player, etc.). Typically the learning problem takes as input a corpus of natural language expressions paired with their corresponding MRL expressions and the output of learning is a component that can map natural language to MRL expressions. We shall drive innovation in this area by defining an MRL adequate to SPACEBOOK's complex, real world task environment, as well as by creating a semantic parsing corpus for the SPACEBOOK domain. This is a clearly sought after resource for the machine learning community, which is currently using only a small number of semantic parsing corpora based on simple scenarios such as booking airline flights. Moreover our approach to structural learning extends the state of the art in learning of natural language understanding components.

IV. **Generating textual descriptions and saliency models of objects in field of views** In GIS systems, traditional representations of space are Cartesian in the form they represent spatial dimensions of objects. By combining a visibility engine with a rich description of geographic entities, SpaceBook affords a way of describing 'place', focusing on entities that fall within the field of view, both near and far. By incorporating textual descriptions and vernacular regions in the city model, we are able to describe the city in a more intuitive manner that maps more readily to the user's perception of the city. This significantly extends the 'spatial vocabulary' that we might use to describe the field of view.

    The combined visibility engine and detailed city model provides a tailored environment in which to explore the efficacy of textual descriptions of 'constellations' of complex geographic objects (text based scene description), in real time (exploring parallel processing and enhancements to spatial statistical algorithms). Such research is fundamental to speech based interaction in highly dynamic environments.

    Theoretical topological models applied to vista space are used to describe the absolute and relative positions of places of interest. This involves modeling egocentric views in rapidly changing vista space, and the generation of egocentric object references (referring expressions). These descriptions are evaluated against a number of metrics, in the context of human subject based navigational tasks in order to assess the 'correctness' of these descriptions against a human's actual perception of that urban space.

V. **Question Answering (QA) systems over textual resources**

    In the past decades, evaluations in the QA research community (e.g. TREC QA, CLEF QA) and in the industry (IBM Watson Jeopardy challenge) have shown that automated systems are increasingly more reliable when tasked with answering certain question types, such as factoids and definition questions. More recent research has focused on handling more complex questions and request environments. In Spacebook, QA is provided as a discovery functionality along with navigation. Our focus is on assessing the integration of existing QA techniques in a larger, multi-task and speech-only mobile system, in particular by making use of Spacebook's simulation of the user's field of view. While mobile applications providing search and city exploration exist (e.g. Field Trip, Google Now currently extending to Google glasses), there is little data on the impact of real street environment and multi-tasking on QA behaviour, and how subjects make use of the technology.

3 Main Scientific and Technological Results

The SpaceBook project initiated with intense requirements collection, partly guided through Wizard-of-Oz studies – where a human operator played the role of the system. This impacted the form and content of the data and knowledge representations underlying SpaceBook. This also impacted the initial design and implementation of SpaceBook components. A range of experimental work contributed to the final design of the SpaceBook system, the implementation of which led to a final prototype based in Edinburgh. It was this prototype that was evaluated through controlled task-based experiments with real pedestrians in central Edinburgh.

Beyond this integration and evaluation work, much work was targeted at the focused areas mentioned above. For example we have investigated the derivation of saliency measures of geographic features in our city model via both web-based text mining and directly from human route directions. We have also pushed QA technology to the limit to support sequences of speech-based queries over documents describing entities in Edinburgh. We have also applied machine learning techniques to information extraction over documents to populate structured relations that may be directly queried. Finally we have explored a variety of alternative representations and processing techniques to support visibility determination, route calculation, dialogue management and the generation of natural language descriptions. A key activity in the project has been to compare and contrast alternative techniques to solve problems within the SpaceBook task domain.

This project has realized a series of integrated prototypes supporting SpaceBookobjectives culminating in a full integrated prototype that was evaluated on the streets of Edinburgh in Fall of 2013. In our deliverable D6.2.2 we present a comprehensive evaluation of this final prototype.

The project has also generated several open data sets as well as a semantic parsing corpus. Specifically we have made a public data release of our WoZ studies (linked from the project website). We shall soon publish a semantic parsing corpus for the SpaceBook domain based on this WoZ data. Finally the data underlying our final evaluation, as well as several side experiments, will be published on our website.

This project has generated a large body of published work [36, 8, 20, 19, 7, 1, 47, 16, 18, 17, 6, 43, 34, 21, 5, 44, 4, 14, 27, 25, 46, 9, 28, 51, 31, 29, 12, 33, 30, 26, 23, 15, 13, 32, 50, 24, 10, 11, 22, 45, 49, 42, 35, 48, 2, 3, 39, 41, 38, 37, 40] (accessible from our project website). Much of this work either documents full or partial system integrations and evaluations, or describes more directed results. To highlight, we have publications that develop and evaluate new methods of compressing belief states to enable more practical use of POMDPs for interaction management. We have publications that develop and evaluate a novel method of probabilistic behavior tracking that scales to thousands of behaviors. We have several publications that develop and evaluate methods addressing the central problem of determining which landmarks in a scene are the most salient, and thus deserving of mention to the user to assist in navigation and exploration. We have reports and publications in process that describe our approaches to advancing speech-based question answering over text sources associated with spatially-located entities. Finally, we have reports and publications in process that present and evaluate learned semantic parsers over the corpus of natural language / meaning representation language pairs we developed in this project.

In addition to our publications we have produced a series of videos that explain our project concept, showcase our city model and pedestrian tracker and demonstrate our working systems. These demonstration videos are also linked on our project website.

We expect that our findings will impact technology development for eyes-free hands-free devices for city exploration. The project has generated implementations, data, corpora and publications over a broad array of necessary sub-components to support the SPACEBOOK vision. Partner's capabilities in these areas have been enhanced through the efforts, collaborations and outcomes developed in this project.

4 The potential impact

The SPACEBOOK project has generated concrete technical and scientific advances for eyes-free, hands-free navigation and exploration systems which support applications in tourism. It also has potential application in rural contexts, and among user communities such as the visually impaired, the cognitively impaired and the emergency services – tasks that must be unencumbered by invasive technology.

Street level experiments revealed the challenges of 'dialogue based technologies'. Under favorable conditions, the concept of 'dialogue only interaction' proved to be an exciting way of exploring the city. The reliability and robustness of the system requires ASR technology that can cope with the ambient conditions of the urban world. We have developed a large body of work and expertise in this area. Various paths to market and use can be envisioned. The goal now will be for us and others to discover a way to get this technology deployed in European cities.

5 Project website

SPACEBOOK's public website address is `http://spacebook-project.eu`.

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