Integrating a Robot in a Tabletop Reservoir Engineering Application

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***Abstract*—We present our work-in-progress efforts of designing a simple tabletop robotic assistant that supports users as they interact with tabletop reservoir visualization application. Our prototype, *Spidey*, is designed to assist reservoir engineers in performing simple data exploration tasks on the interactive tabletop. We present our design as well as preliminary findings from a study of *Spidey* involving both interaction designers and reservoir engineers.**

***ACM Classification Keywords*—H.5.2. User Interfaces: Interaction styles**

***Keywords*—tabletop robots; robotic assistants; social robots; human-robot interaction; tabletop interaction.**

I. Introduction

Robots' physical presence and agency can deeply impact and affect familiar interaction scenarios [2, 3]. We believe that introducing robots into a tabletop interactive environment will open up a range of interaction possibilities that can alter the current ways in which people use tabletops. To explore these possibilities we present *Spidey*, a prototype tabletop robot designed to assist and collaborate with reservoir engineers as they explore an interactive tabletop visualization data exploration application running on the Microsoft Surface.

Interactive tabletop robots have been introduced in the past for scenarios such as games [4, 5], and performing fine-grained manipulations [6]. However, they were generally not designed to be task-oriented, and were not considered as assistants for subject-matter expert (SME). In such sense *Spidey* is unique and novel in its design and application. Apart from its physical agency, *Spidey's* interactive advantage is that it is aware of the virtual task realm as well as of the participants physical actions manifested as touch on the tabletops. Thus, the robot can help user in performing their tasks both physically and virtually. Tabletop robots such as *Spidey* can help users in collaborative settings by either serving as a tool or by acting as an interaction collaborator exchanging knowledge with human-users working around the table.

In this report we present the design, implementation and preliminary evaluation of *Spidey* and our current efforts of integrating it into an existing tabletop reservoir engineering application [7, 8]. Our long term goal is to learn more about human-robot interactions in the unique settings of an interactive tabletop, and to know how tabletop robots can enhance social user experiences in a task-oriented environment. Given the explorative nature of our approach the current questions we attempted to answer were whether a tabletop robot would even be accepted as a valid interaction aid by experts who are using the tabletop environment for their tasks.

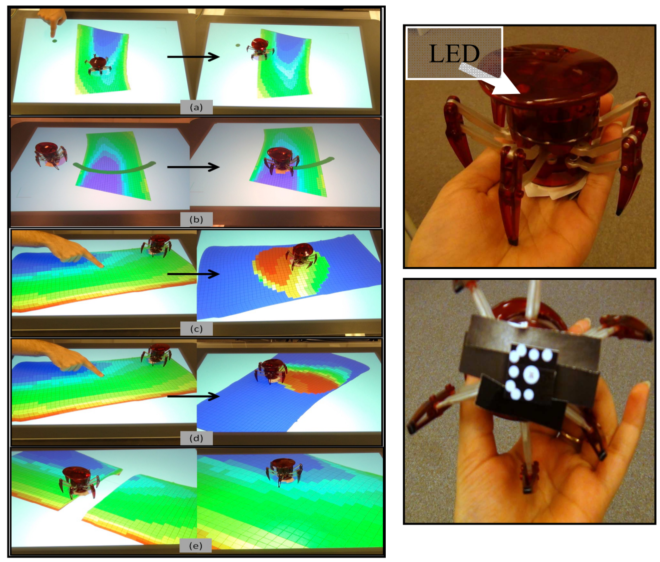

Figure 1. Spidey and its tasks: (a) Tap and Call, (b) Draw and call, (c) Reveal, (d) Reveal and Rotate and (e) Playback.

II. Spidey – Design and Implementation

The current prototype of *Spidey* is designed for the multi-touch Microsoft Surface I (Figure 1). *Spidey* is a small commercial spider-like HEXBUG toy robot integrated to work within a reservoir visualization application framework. *Spidey's* small size helps to reduce occlusions of the digital content as it walks the tabletop surface and, lower interferences to other (human) users interacting on the Surface. *Spidey* can move forward, backward and rotate left and right in 360^o. The blinking LED at the tip of its head gives the perception of it having an eye, and its six small legs are somewhat similar to human fingers touching the tabletop. In practice, and unknown to the user, *Spidey* is not autonomous in any way. The surface PC is continuously tracking and fully controlling the robot, and, if needed, is responsible for augmenting the robot vicinity with visual formation, creating the illusion that the robot was the one initiating the action via direct touch to the Surface. *Spidey's* physical reaction, for example, its movement and head turning, create a lively illusion and impression that the robot is performing its various tasks autonomously and intentionally. *Spidey* is controlled by an IR remote control, located above the Surface, which in turn is controlled by the Surface PC to enable signals to be sent to the robot. To enable real time tracking of the robot we attach a byte tag, tracked by the Surface, to the bottom of the robot's body.

III. Spidey and Reservoir Engineering

To learn about the primary requirements for designing *Spidey's* assistive behavior we integrated it within a tabletop reservoir visualization application we developed [7, 8]. The selection of this domain as a testbed is based on the rationale that reservoir engineers often work in a collaborative setting learning from each other. Thus, employing a robot can help them in different scenarios – potential collaborator, assistant, mediator, tool etc. (however, the same argument could be valid to other collaborative applied domains and tasks).For the purpose of the study and to facilitate thinking during the discussions with our domain experts, we implemented the following five *Spidey* tasks (Figure 1):

1. Tap and Call – using this technique users can call *Spidey* to different regions of the reservoir model by simply taping on the destination point using a single finger (Figure 1a). Upon removal of the finger, the robot begins to walk towards the destination and stops when reaching it.

2. *Draw and Call* – is similar to Tap and Call, but instead of a single destination point, the user can draw a path that the robot should follow to reach the destination on the reservoir model (Figure 1b). This can be useful in scenarios when engineers would like to collect data along a particular path or region.

3. *Reveal* – a reservoir engineer often needs to examine two or more geological properties simultaneously [8]. Using this as a rationale we developed the reveal task, wherein experts can call *Spidey* to different regions of the reservoir model to reveal different property information (Figure 1c). This can be useful in scenarios where *Spidey* can gather information from different parts of the reservoir model while the expert can concentrate on other tasks.

4. Reveal and Rotate – is similar to reveal in terms of information retrieval, but the added advantage is that the robot can now also be used to perform reservoir manipulation tasks such as 3D rotation, zoom etc. (Figure 1d). The rationale behind this task is to allow novice users of the system to continue exploring while *Spidey* presents different views of the model. Reveal and rotate can also be useful during demonstration of reservoir properties to colleagues.

5. Playback – unlike the other tasks (1-4), which portray *Spidey* more of as a tool, playback is designed to present *Spidey* as a mediator or as a potential collaborator. Playback is a task wherein *Spidey* plays back a set of recorded actions performed previously by others, potentially in a completely different location, acting like their physically recorded fingers. To demonstrate this, we fabricated a sequence of tasks (splitting of the reservoir, zooming, rotation and merging of the reservoir model [8]) to be played back by *Spidey* (Figure 1e). The motivation behind playback is to allow *Spidey* to become a sort of interaction mentor which can play back complex reservoir exploration actions tasks as performed by expert users, in order to allow others to learn from. We believe that playback can be particularly useful tabletop interactive scenarios which emphasize presentation and learning.

IV. Evaluation and Conlusion

A preliminary qualitative study was conducted with ten domain experts from our University; five reservoir engineers and five computer scientists. The study sessions involved three components in the following order – pre-session questionnaire, demonstration of the tasks and discussions (main session), and finally a post-session questionnaire.

1. *Pre-session questionnaire*: In this questionnaire we asked our participants to define the word 'assistant' using three simple descriptive words or sentences. From the responses, we observed that the most common definitions associated with the term assistants were: task-oriented, helpful, punctual, smart and quick.

2. *Main session*: In this stage of the study, we demonstrated *Spidey* and each of its tasks, and encouraged our participants to try the tasks while thinking aloud expressing their experience and feedback. From our discussions we observed that *Spidey* was liked by the majority of our participants, with the exception of two participants mentioning it to be somewhat "scary and creepy". Three participants mentioned that a spider-like robot may however be misfit in the context of these tasks, emphasizing the importance of physical form when designing robotic assistants. Participants were overall enthused about the robot's physicality, movement, and its actions. Responsiveness and accuracy of the robot were also questioned during the discussions, with a few reservoir engineer participants suggesting that the robot needs to be faster and more accurate to be considered useful for domain tasks. A need for better reservoir model exploration tasks and more autonomous behavior was also expressed by most of our participants. In terms of assistance, all the participants found at least one of their definitions (defined at pre-session stage) being met by *Spidey*, with two participants finding *Spidey* to match all of their initial definitions of an 'assistant'.

3. *Post-session questionnaire:* we used Bartneck et al.'s HRI questionnaires [1] for this stage with an added question about companionship. The responses indicated that majority participants liked *Spidey* (mean: 4.0/5.0) and that the robot was above average in terms of companionship (mean: 3.50/5.0) with one domain expert scoring it a 5.0 for companionship, life-likeliness and friendliness.

Overall we observed that a tabletop robotic assistant can prove to be beneficial with the right kind of task and interaction design. In the future we would like to improve our prototype by designing appropriate assistive tasks and gather detailed user study observations.

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