Producing Verbal Descriptions for Haptic Line-Graph Explorations

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1 Verbally Assisted Haptic Graphs

Combining haptic graphs and verbal information in a multimodal human-computer interaction scenario is a promising means to make statistical graphs accessible to blind people. For example, users can explore haptic graphs by hand-controlled movements using a stylus of a force-feedback device gathering information about the graphs geometrical properties (Acartürk, Alaçam & Habel, 2014). In the present paper we look on haptic graph exploration as a collaborative activity of two agents, a (visually impaired) explorer (E) of a haptic graph and an observing assistant (A) providing verbal assistance (Habel, Alaçam & Acartürk, 2013; Alaçam, Acartürk & Habel, 2014; see Fig. 1). In particular we focus on one technical aspect in building a common ground between human explorers and computational assistants. (Sect. 2 & 3).

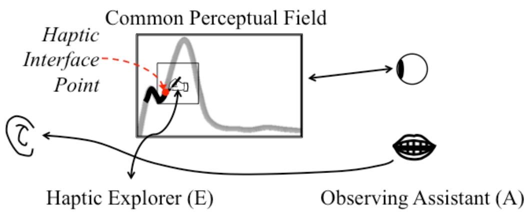

Figure 1. Assisted haptic graph exploration

In our empirical studies (Alaçam, Acartürk & Habel, 2014), the agents share a common field of perception, namely the haptic graph and its exploration, but their perception and comprehension processes differ substantially. For example, while E explores the segment of the haptic graph on a horizontal virtual plane that is the highlighted, black in Fig. 1, A perceives visually the global shape of the graph and E's exploration movement on a vertical computer screen.

The success of verbally assisted haptic graph comprehension depends on the alignment of the interlocutor's internal models, especially on building implicit common ground (Garrod & Pickering, 2004), as well as, on producing adequate utterances. The recognition of exploration events by the verbal assistant system is one of the crucial processes that ground alignment and make the communication between E and A efficient and effective.

2 Recognition of Exploration Events

For giving verbal assistance, A has to observe E's exploration movements, with other words, beyond considering the current location of the exploration movement, i.e., the haptic interface point (see Fig. 1), A has to analyze the ongoing exploration event. And in the long run, A has to consider the history of exploration events as well as the history of produced utterances.

In the following we give a short overview of how exploration movements are recognized in our OBSERVINGASSISTANT prototype:

- The haptic-graph knowledge base contains spatial information about the 3D haptic model of the specific line graphs, information about the their geometry (Kerzel & Habel, 2013) and also line-graph specific information, like positions and properties of graph landmarks like extrema and slopes.
- Haptic exploration-event recognition is performed by a rule based system (RBS) in a two-step process:
  - *Recognition of basic events*, i.e., of events that are perceivable, momentary changes in movement behavior or position with regard to segments or graph-landmarks in the virtual haptic environment. Detected basic events are inserted into the knowledge base.
  - *Rule-based complex event processing:* From perceived basic events, a rule based system, interprets basic events and constructs complex events. This system is realized in

DROOLS using a rule language based on first order predicate logic with an added temporal calculus (see, Kerzel, 2013).

- Recognized exploration events and also updates to ongoing exploration events can be used to trigger system reaction. In the current stage of development using canned text assisting speech is realized using the text-to-speech platform MARY (Schröder & Trouvain, 2003).

3 The ObservingAssistant at Work

In the following we exemplify the processes of event recognition with a short sequence of exploration movements. Figure 2 depicts, firstly, a segmented and annotated graph as it is represented in the haptic-graph knowledge base, and secondly, a segment from an exploration movement of a user (depicted by red lines); the user can not perceive the representational features depicted in Figure 2.

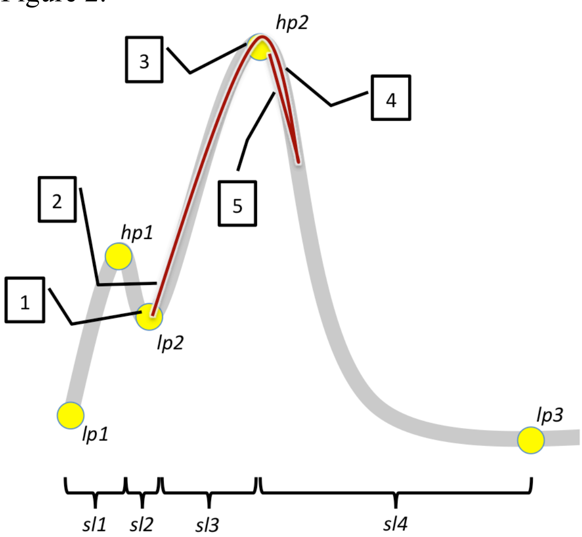

Figure 2. Analyzed exploration trajectory (red) and depictions of some content in the haptic-graph knowledge base. The numbered boxes correspond to the steps discussed in this section.
Representational features: Yellow dots ≈ local / global extremum (*lp* – minima, *hp* – maxima); horizontal curly brackets ≈ projection of *slopes* (*sl*) to the x-axis.

Step 1: The exploration starts with the haptic interface point being positioned in the local extremum *lp2*, where two slopes, namely *sl2* and *sl3* meet. By beginning to move to the right (upwards) a basic event of being in this slope is detected. The RBS recognizes that this slope is currently explored and inserts the resulting exploration event into the knowledge base. Additionally, this event can trigger canned text frames that lead for example to. "*You are exploring a steep slope in the first quarter of the graph.*"

Step 2: The user's stylus movement goes on along the slope *sl3* in the right upward direction. A basic movement event including the movement direction is detected and therefore accessible by the RBS. Considering the geometrical properties of the currently explored slope, which are stored in the knowledge base, the next relevant graph landmark that the user is approaching is identified by RBS as *hp2.* This triggers further verbal information in a look-ahead style: E.g. "*You approach the second maximum of the graph. It is the global maximum.*"

Step 3: The user reaches the maximum *hp2*. A corresponding basic event is detected. This event is also subsumed under the ongoing exploration of the slope *sl3*. The RBS reasons that the ongoing exploration event is completed since both endpoints of the slope were visited. This leads to uttering: "*You fully explored the upward slope.*"

Also an ongoing exploration event of the high point is created. Thus a further, domain dependent specification of the explored graph-landmark can be verbalized: *"You reached the global maximum of 94."*

Step 4: The user's exploration goes on beyond the maximum and enters the next slope, *sl4*, which is recognized by the RBS: An extended exploration event regarding this slope is created and together with the movement information (the user is still moving from left to right) assistance is triggered: "*You are now descending a very steep slope.*"

Step 5: The user stops and moves back to the high point *hp2*. When the user reaches the maximum, an exploration of *hp2* is recognized again. Due to the RBS'—currently even rudimentary—bookkeeping of exploration events and utterances, the assistance "*This is the global maximum again."* is given.

4 Conclusion

Haptic line-graph comprehension can be enhanced by verbal assistance. The rule-based ObservingAssistant reported above analyzes the users' exploration movements and triggers reactively canned text, which is realized by the MARY text-to-speech system. The next version of the ObservingAssistant will be extended on the basis of empirical studies on human-human assistance (such as, Acartürk, Alaçam, & Habel, 2014; Alaçam, Acartürk & Habel, 2014).

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