
Leveraging Multimodal Dialog Technology for the Design of Accessible Science Simulations

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Abstract

We present an accessible interactive science simulation that leverages multimodal dialog technology. Traditional science simulations typically feature interactive graphical interfaces which are not suited to visually impaired learners. We alleviate this problem by developing spoken dialog applications using HALEF – an open-source standards-compliant cloud-based dialog system – that enables visually impaired learners to interact smoothly and efficiently with such simulations by using just voice input. We argue that such technologies could significantly improve the quality of STEAM education, particularly for students with accessibility challenges such as visually impaired learners.

Author Keywords

multimodal dialog systems; accessible simulations; voice input

ACM Classification Keywords

10003120.10003121 [Human-centered computing]: Human computer interaction (HCI)

Introduction

Multiple research studies over the past few years have shown that the percentage of students with disabilities pursuing degrees or employment in science, technology, engineering, art and mathematics (STEAM) are significantly



Figure 1: Screenshot of the *John Travoltage* static electricity simulation developed by PhET.

lower as compared to their non-disabled peers (see for example [3, 4]). Visual impairment in particular presents numerous challenges to classroom learning, particularly in STEAM fields where instruction relies heavily on graphically conveyed information, such as charts, graphs, diagrams, engineering drawings and 3-D simulations [2]. One way to circumvent some of these issues is to increase the use of audio and speech-based accessible tools in classrooms and laboratories [9]. However, there is still much work to be done in this regard. This is due to several barriers – widespread availability issues, technology costs, varying levels of technology literacy, issues of adequate and appropriate support and maintenance – to name a few [1].

The HALEF Dialog System

The multimodal HALEF dialog system depicted in Figure 2 – also see <http://halef.org> – leverages different open-source components to form a spoken dialog system (SDS) framework that is cloud-based, modular, and standards-compliant. For more details, please refer to [7]. Note that this system has already been successfully deployed in multiple conversational English language learning applications – see for instance [6]. One can also explore some of these dialog tasks on the web at <http://englishtasks.com>.

Against this backdrop, this paper argues for the increased use of cloud-based and low-cost spoken dialog based technologies in the classroom to bridge this accessibility gap and afford students with visual impairments more effective and impactful learning opportunities. Dialog technologies have the potential to overcome several of the barriers listed above: using such cloud-based systems at scale allows them to be relatively cost-effective and widely accessible from a range of devices and geographical locations, while remaining easy to use for students with visual impairment as it just requires interaction through spoken input. The rest of the paper discusses an exemplar prototype in this vein that allows learners with visual impairments (as well as other learners) to interact with a physics simulation through conversations with a dialog system.

System Design and Implementation

We chose the *John Travoltage* interactive simulation¹ created by the PhET Interactive Simulations project at the University of Colorado as a basis for our system design [8]. See Figure 1 for a screenshot of the simulation. In *John*

¹<https://phet.colorado.edu/en/simulation/john-travoltage>

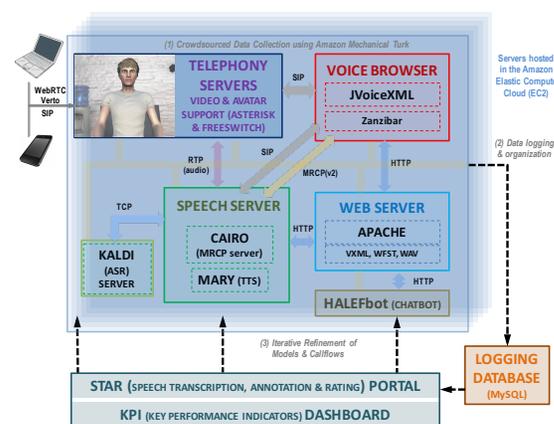


Figure 2: The HALEF multimodal dialog framework that supports educational learning and assessment applications (©Authors).

Travoltage, students explore concepts of static electricity including transfer of charge, repulsion, and grounding by playing with an interactive graphical simulation wherein they can either rub John’s foot across the carpet to accumulate static electricity (which can be simulated by dragging John’s foot across the carpet using the mouse pointer) or move John’s finger closer to the door knob to discharge charge built up by the rubbing of his foot. Students can therefore graphically interact with the simulation to develop a better understanding of questions such as how arm location and charge accumulation affect discharge, the comparison between charging and discharging processes, etc. However, notice that this simulation relies to a great extent on visual interpretation of the current state of the simulation to take subsequent action, which is not suitable for visually impaired learners. While one can improve the accessibility of these simulations using haptic technologies and sonification [10, 5] as well as enhancements such as making the application more screen-reader-friendly, the user experience of visually-impaired learners can be greatly enhanced by leveraging spoken dialog to augment these technolo-

gies. This is because spoken language input (in addition to spoken output) can benefit users who have difficulty (or are unable) to access the simulation using touch, mouse, or traditional alternative input options, as well as “hands busy” scenarios, where a teacher or student may be using their hands to demo something physically simultaneously with using the simulation.

To this end, we leveraged the open-source HALEF dialog system mentioned earlier to develop an accessible version of the above simulation where students, including those with visual impairments, can interact using spoken dialog. Table 1 shows the transcript of an example conversation between a human learner and the dialog system for the *John Travoltage* simulation task. Observe that such a simulation can allow visually impaired learners to experience the simulation more effectively relative to the graphics-only simulation, thus coming closer to bringing all populations – whether disabled or not – on a more even footing.

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Conclusion and Outlook

We have argued for the increased use of accessible spoken dialog technologies in the classroom for STEAM education to level the playing field for students with disabilities, particularly those with visual impairments. We further presented a prototype implementation of a science simulation using spoken dialog. Future work will focus on integrating the dialog-based version of the simulation with the graphical version to allow for more flexible user control. We will also conduct user experience studies with blind and low-vision users, that will allow us to test and improve the system in an iterative manner.

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Table 1: Example dialog between a human learner and the HALEF spoken dialog system in the case of the John Travoltage static electricity simulation application. This replicates the functionality of the original interactive graphical simulation to a certain extent while remaining accessible to visually-impaired learners in particular. Note however that this interaction was between a sighted individual and HALEF.

Speaker	Dialog
HALEF	John is standing on a rug next to a door in a room. He is pointing at the doorknob with his index finger, but not touching it. There is a gap of 3 centimeters between the tip of his finger and the doorknob. His hand can move closer and further away from the doorknob. His right foot can brush against the rug.
HALEF	Your mission is to determine how to get a spark from John's finger by manipulating the charge he contains and the distance of his finger from the doorknob. You need to determine how distance and charge interact to produce the spark, and the relationship between the two quantities. When you have figured it out, we would like you to answer two questions about this relationship. Would you like to know what you can do during this simulation?
Human	Yes, please.
HALEF	You can move the finger 1 centimeter at a time closer to or further away from the doorknob. You can rub the foot once on the rug. You can get an update on the current charge difference between John and the doorknob and the current distance between the tip of the finger and the doorknob. You can reset the finger and charge to their original settings. You can review this list of options, you can go to the exit quiz and you can exit the program without taking the quiz. What would you like to do now?
Human	Please move the finger closer to the doorknob.
HALEF	The finger is now one centimeter closer to the knob. The finger is 2 centimeters from the knob. No spark is produced by this change. Keep making changes by moving the finger or rubbing John's foot. What would you like to do now?
Human	Rub John's foot, please.
HALEF	Before rubbing his foot, John has a charge of 0. After rubbing his foot, John has a charge of 1. No spark is produced by this change. Keep making changes by moving the finger or rubbing John's foot. What would you like to do now?
Human	Rub John's foot again, please.
HALEF	Before rubbing his foot, John has a charge of 1. After rubbing his foot, John has a charge of 2. No spark is produced by this change. Keep making changes by moving the finger or rubbing John's foot. What would you like to do now?
Human	Move John's finger closer to the door.
HALEF	The finger is now one centimeter closer to the knob. The finger is 1 centimeters from the knob. A spark jumps from John's finger to the doorknob!
HALEF	What would you like to do now?
Human	I'd like to exit, please.
HALEF	I notice you haven't taken the quiz yet. Would you like to try the two questions before leaving?
Human	Yes, why not?
HALEF	What do you think the relationship is between the distance between John's finger and the doorknob, and the charge difference between John and the doorknob?
Human	Seems to be a 1:2 ratio of distance to charge required to cause the spark.
HALEF	Here's a little math question. John's body has a charge of 12 and his finger is 10 centimeters from the doorknob. As he moves his finger closer to the doorknob, at what distance will a spark first occur?
Human	6 centimeters.
HALEF	That's right! Thanks for testing our simulation! Your next command can be Exit or Reset. What would you like to do now?
Human	I'd like to exit the simulation, please.
HALEF	Thank you again for participating! Good-bye.