Demonstration: Screen Reader Support for a Complex Interactive Science Simulation

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ABSTRACT

Interactive simulations are increasingly important in science education, yet most are inaccessible to blind learners. We demonstrate an accessible version of a simulation, *Balloons and Static Electricity*, that illustrates responses to key challenges in providing screen reader support: the need to describe unpredictable sequences of events, the manipulation of objects that act as both controls and displays, and the management of descriptions of changes in the state of the simulation as well as of the state of the interactive object, itself. Meeting these challenges requires extending current practices for verbal description of visual interactive content.

Keywords

Description; Accessibility; Visual Impairment; Usability Study; STEM Education; Interactive Science Simulation; PhET Simulation

1. INTRODUCTION

The availability of cheap, fast computers, with excellent graphics capability, and appropriate software tools, has led to the creation of large numbers of interactive simulations (“sims”), aimed at helping students understand concepts in many fields. Many are widely used; for example, the sims by the PhET Interactive Simulations project (<http://phet.colorado.edu/>) are run over 75 millions of times a year. But these sims use dynamic visual representations of science concepts, and mouse- and touch-driven interaction, that present barriers for learners who cannot see.

Figure 1 shows two screen shots from the *Balloons and Static Electricity* sim that we demonstrate. It allows a learner to rub a balloon on a sweater, and observe the rearrangement of electrostatic charges that result, as well as the consequences (for example, the balloon being attracted to the sweater or to the wall).

A number of approaches to making sims like this accessible can and should be explored. It may be possible to use dynamic tactile displays (though the small-scale electrostatic charges would be a challenge). There may be other nonvisual and engaging ways to convey the underlying content of the sim, such as the text-based command-response interactions seen in text adventure games.

The approach we demonstrate meets two constraints arising from the pedagogical use of the PhET sims. First, it must not require Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the Owner/Author.

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hardware not widely available in classrooms today. Second, the accessibility features must be incorporated in the same sim used by sighted learners.

Figure 1. PhET Sim, *Balloons and Static Electricity*. (A) Sim on page load. (B) Negatively charged Balloon sticking to positively charged Sweater with keyboard focus (pink outline).

2. APPROACH

To meet these constraints, we designed and implemented 1) infrastructure, the *Parallel Document Object Model (PDOM)*, to support communication between the sim, a web browser, and a screen reader 2) keyboard navigation and interactions, and 3) descriptions to be read by the screen reader.

The PDOM is a data structure (built in Hypertext Markup Language, HTML) that represents the objects in the sim, such as the balloon, in a form that can be accessed by a screen reader program. This had to be added because, like most such programs, the preexisting sim on which we are building used graphical representations that cannot be accessed by a screen reader.

With the PDOM as an invisible layer on top of the visual sim, a blind learner can navigate much of the sim using familiar keyboard interactions and screen reader commands. However, some interactions required a customized approach. We designed custom hot keys to move the balloon quickly to important areas within the sim and to drag and rub it against other sim objects.

3. DESCRIPTIONS

The remaining design and implementation work focused on the descriptions to be read by the screen reader while the simulation is in use. An active range of work [1,2,3,6,7] on making diverse types of static and interactive science content accessible through the use of natural language is ongoing. In the iterative design and evaluation of our sim, we found that we needed to go beyond the recent guidance available for simple interactive scientific graphics [4]. We describe here the new challenges we encountered, and our approaches to them.

3.1 Unpredictable event sequences.

When describing a video, the describer knows the sequence of events, and can devise a description that works well for that fixed sequence. In an interactive sim, one knows the events that may occur, but not the sequence in which they will occur. This requires

that descriptions be written modularly, so that event descriptions are intelligible when reordered and recombined.

The descriptions we demonstrate are adequate in this respect. But we believe more sophisticated methods should be developed, in which redundancy is reduced by making descriptions history dependent: the description of a second occurrence of an event should be shorter than the description of the first.

3.2 Objects as controls and displays.

Existing guidance on interactive diagrams [4] supports situations in which a learner controls the visual by setting parameters, e.g., by using a slider. While many interactive sims include this kind of control, other kinds of interaction are common. In our case, the balloon poses special challenges. It behaves somewhat like a control, in that moving it changes the state of the sim. But its role cannot be reduced to controlling a simple parameter, because rubbing the balloon on the sweater has different effects from rubbing it elsewhere. Further, the balloon also acts as a display, in two ways. First, visual indicators of electrostatic charges are shown on its surface. Second, if the balloon is released, it may move on its own, as it is attracted to other objects. Thus the balloon is not a control separate from the sim, but in fact part of it.

These complications required us to provide three distinct forms of description for the balloon. First, as a learner explores the simulation by navigating the PDOM, they will encounter the balloon as an object in the sim, and need a description of it. This includes the amount of charge on the balloon, its position, and its effect on nearby objects. Second, when the learner wants to interact with the balloon, they need a description of how to use it. Since the balloon is not a standard HTML control, users would not be familiar with the drag and release interaction from prior experience. Third, when the learner acts on the balloon they receive a description of the effects of the action, discussed next.

3.3 Describing states and state changes.

The action of rubbing the balloon on the sweater has two effects. First, it produces a *new state of the sim*: the distribution of charges after the motion is different from what it was before. Second, it *makes something happen*: negative charges move from the sweater to the balloon. These two aspects are integrated for sighted learners: they immediately see the new distribution of the negative charges as they disappear from sweater and instantly appear on the balloon. Blind learners see neither of these things.

We demonstrate descriptions that distinguish these aspects of the sim, using descriptions provided in two ways. The current state of any object, for example the charge on the balloon or the sweater, is given by a description as part of the element representing the object in the PDOM. The learner can access the current state information by navigating the PDOM. In addition, when the learner takes an action that makes something happen, they receive a description of the effect of the action, immediately. Changes to both types of descriptions are announced to the learner via ARIA Live Regions, a technical means of directing a screen reader to read out a change in the sim that is outside the student's current reading location (i.e., cursor focus). Thus both types of descriptions, the *new states* of the objects affected by the action, and the description of the change (i.e., *what happened*), are provided. The newly announced state information is the changed description available in an element in the PDOM. It is announced to connect the learner's actions with the changes. This state information can be reviewed or listened to again by navigating the PDOM. The description of the change; however, only makes

sense at the time of interaction. Thus, it is stored as hidden content in the PDOM to prevent hearing it out of context.

4. DISCUSSION

Existing research and resources provide very useful strategies for describing static content and simple interactive graphics, and are applicable to many aspects of more complex scenarios. But we found challenges unique to complex interactive simulations.

Our response to these challenges, as demonstrated was to:

- Create modular descriptions that can be reordered to accommodate unpredictable event sequences.
- Provide differentiated descriptions for objects that serve both as controls and as displays in the simulation.
- Recognize the need to provide separately (a) access to the current state of the objects, (b) access to new state information when actions are taken, and (c) descriptions of changes caused by actions.

We have explored in a limited way how point (c) might be supported by sonification [5], using sound together with language to convey information about dynamic processes like movement. This is one example of further work we and the research community can pursue, to increase accessibility of this important class of educational tool.

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