

# Using Force Fields as a User Interface Device

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## Abstract

*This paper discusses the use of force fields as a means of passing advice from a computer program to a user. It is suggested that this mechanism can be used as a replacement for traditional user interface pop-ups or other widgets when the task is a three dimensional one and a haptic device is available. The benefits and limitations are presented, along with a description of an example prototype application in the underground mine planning domain.*

## 1. The Problem

During the course of an interactive computer program, there are typically times when the program logic determines that some information needs to be passed to the user. The simplest case of this is the pop-up message box, often advising the user that they have violated some rule. In a 3D application, these messages may take the form of “you are too close”, “too far”, “too steep”, “too thin” etc. The user typically needs to pause what they are doing and acknowledge the message, usually by clicking on a button. In a traditional, 2D application this can be disruptive to the flow of work. In a 3D task, the disruption can be greater because of the need for the user to move their interaction tool in 3D from their work location to the pop-up. If they were grasping, drawing or pointing at something, they may need to abandon their interaction to react to the message. Controlling a 3D interaction device is inherently more difficult than a 2D one (such as a mouse) because it lacks the stability and friction of a surface to rest on. Returning to the point of interaction after moving away can therefore be more difficult than with a 2D mouse and cursor.

The flow of information to the user may not just involve binary messages. Continuously varying data may also need to be conveyed to the user. An example of this might be the distance between two movable objects. A visual user interface widget for this may

take the form of a gauge, color bar or arrow in the scene. These widgets may take up valuable view space and clutter the scene with objects that are ancillary to the ‘real’ objects being depicted. They may also require the user to shift their gaze away from the task at hand to observe the measurements.

## 2. A solution using force fields

In any 3D virtual environment, a haptic interaction tool can assist the user in the manipulation of objects. With the benefit of haptics (force feedback), the user can reach out, touch and grab objects that they need work on. This eases the dependence on the use of eyesight to co-locate a virtual tool with the target. With a touchable surface on the virtual objects, a faster, more natural way of working on them is available. Although this is the most common way of using haptics in virtual environments, alternate uses of haptics are possible. Such an alternate is to use *auxiliary haptics*, i.e. using a haptic effect to assist the user by providing status information about the current virtual environment in the form of a force on their hand. If the program logic needs to pass on advice to the user, as mentioned in section 1, above, and if this advice has some directional component (i.e. it can be expressed as a vector), then we can introduce a force to the haptic device that effectively guides the user in the correct direction. This force can be applied selectively at certain times and in certain parts of the 3D scene, as required. It is therefore analogous to a force field that has a location, direction and extent, and can ‘wax and wane’ as necessary.

The use of such force fields can have several benefits:

Firstly they can represent *advice* but not necessarily *enforcement* with hard barriers such as is described in [1]. We would typically want the user to have ultimate control over the system, since they would be the expert on the particular task at hand – if the computer could perform the task better, there would be no need for a user at all and the task could be completely automated. A gentle force field of variable intensity can advise the

user of some rule violation, but not force them to obey the advice. An example might be “you are getting too close to this object”. The user’s reaction might be verbalized as “OK, but this time I still need to go just a little closer before moving away”.

Secondly, a force field can provide continuous advice. It is not binary such as a pop up message. More importantly, the advice can be continuously varying in intensity and direction. This is most appropriate when the information being represented is of a continuous nature.

Thirdly, if used appropriately, it can be very intuitive. In the example of being too close to something, the force is physically pushing the user away, a very intuitive interface, much like an expert’s guiding hand. There is no learning curve or explanation required to understand the mechanism.

Finally, it takes up no view space, does not clutter the visual scene and does not divert the user’s attention away from their task. They don’t need to move their interaction tool to acknowledge it.

### 3. Mine Planning Application

To test these ideas we implemented a prototype application to be used by a mine planning consultant when planning a decline into an underground mine. As opposed to a vertical mine shaft, a decline is a steeply sloping underground road that is used by trucks to shift the ore to the surface. The designing task involves drawing the proposed route in a 3D space containing some of the critical geological features. A 3D immersive view is of immediate benefit for producing the initial sketch.

Since the trucks do thousands of journeys over the lifetime of the mine, the goal is to achieve the minimum road distance from ore face to dumping site. However, there are certain restrictions on the route that the decline can take. Obviously it should pass close to, but not necessarily through the valuable ore. As well as this, the safety of the route must be taken into account. The road must not be too steep, must have navigable curves and must avoid dangerous areas such as water-logged or unstable rock. These constraints can be implemented as rules within the logic of the drawing program. Such rules fit nicely into the description above, in that they involve three dimensions, are continuous and need to be conveyed to the user without interrupting their work.

We have built an interface which provides the designer with a 3D view of the geology using the CSIRO haptic workbench [2] (figure 1). This uses stereo and 3D vision, along with co-located haptics via a SensAble Technologies Phantom [4], to produce a

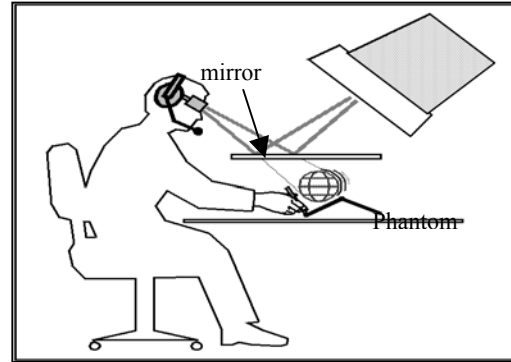


Fig. 1. The CSIRO haptic workbench

desktop immersive virtual environment. The haptic tool is represented in the scene as a 3D pen, which can draw in space when the tool’s button is pressed (figure 2). We have integrated three types of force field into this environment. The first is a repulsive force emanating from dangerous zones within the geology. As the user’s tool approaches these areas, they feel a force pushing them away. This force is inversely proportional to distance, so the closer they are to danger, the greater the force. Users should find this very intuitive and effective in guiding them around the dangerous areas. Often there are dangerous areas in close proximity to each other. In that case the user can ‘squeeze’ the road between two or three zones of repulsion, using their expert knowledge to allow a slight degree of rule violation, if there is no alternative.

The second force field prevents them from drawing a road that is too steep for the trucks to handle. This guides their hand upwards as they approach the maximum gradient. If that maximum is reached, they hit a hard constraint which prevents them from drawing anything steeper.

The third force was designed to prevent the designer from drawing a curve radius that was too tight

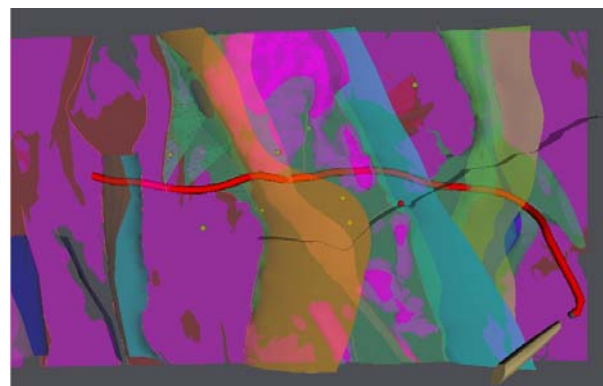


Fig 2. Mine Planning Application showing sketched line amongst ore bodies.

for the trucks to negotiate. The intention was to detect when a curve was being drawn and provide a 'haptic groove' in space that assisted the user to draw a curve in the detected direction and of the optimum radius. We were unable to get a satisfactory result with this part of the prototype. Either the system would detect curves when they were not intended or it would come into effect too late.

### 3. Future Work

We are planning to do user trials to compare haptic guidance with various types of graphic and audio guidance. This should be able to determine if using auxiliary haptics can improve the efficiency of a 3D task, and we hope to report on the results soon.

### 4. Other possible uses of this technique

The use of haptics to convey rules to a user could be applied in other areas. In CAD programs, haptics could be used to connect the manipulation of objects to some internal rules specific to the domain of the designing task. For example, if the task was designing an automotive engine block, the user might be juggling certain measurements, such as the thickness of the cylinder walls. Typically, there would be an optimum cylinder wall thickness, with a degree of tolerance around it. As the user dragged a slider bar, adjusting the thickness, the haptic force might indicate to them that they were diverging from the optimum thickness.

In surgical training, forces could be used to guide the student in the manner of an expert's guiding hand. In more abstract domains, such as economics and finance, haptics could perhaps be used to relay varying financial information to the user.

Certain types of data may be better interpreted if they are mapped to a haptic force. An example of this is an application to interpret 3D seismic data, with the auto-correlation of the data being mapped to a haptic force [2]. This produced an effect where features of the data felt like ridges and troughs. Other aspects of the data were rendered graphically. The user can then easily move around the 'troughs', perhaps sketching in some annotation.

### 5. Summary

The use of haptics can go beyond the representation of the touch and feel of simulated real world objects. It can be used as a user interface device to convey rules to the user. The interface can be intuitive, continuous

and can be accepted by the user as advice without requiring adherence to that advice. It gives the user the ability to override the advice or allow compromise between conflicting constraints.

### 6. References

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