LeapFrog3D: Enhancing the Interface

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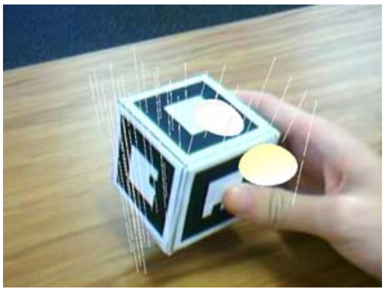

1 Introduction

Leapfrog 3D is 3D visualization software for geological modeling focusing on the mining domain. The tool allows users to filter, analyze and visualize different types of underground measurements (drill hole, seismic data, etc.). The software provides a much faster way of generating possible raw grade morphological models compared to the long explicit modeling sessions needed with current classical tools. By using implicit modeling and a proprietary interpolating algorithm (fastRBF^{TM}), geologists can simply introduce an interpreted morphological model, and the software will converge rapidly to a new meshing solution (Figure 1).

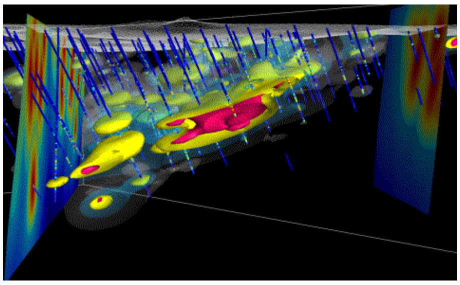

Figure 1: 3D Visualization on Leapfrog3D

This report is a response to the company request to explore new interface tools that can assist with **product presentation** and also provide easy navigation with a better depth perception. Moreover, the company is also interested in exploring the possibilities of a Post-WIMP[1] Interface. We present in this document requirements identified during our observations and discussions, following by a review of current state of the art interface techniques (section 3) and a selected of possible solution ideas (section 4).

2 Observations

After some discussions with members of the company and observations of the software, in this section identify the desired user population and the require-

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[1] Windows, Icons, Menus and Pointer

ments for a data mining software interface.

2.1 Population

There are two main categories of potential users: **standard and presentation users**.

The standard user has a background in geology, and is a specialist in the field with both knowledge and experience. His or her main characteristics are:

- an expert user (familiar with the software interface)
- uses the software for long periods of time interleaved by others activities (during data computing)
- used to accurate and complex modeling tasks
- focused on the details of the dataset

In addition we assume that most of the time using the software is taken up with observation tasks interspersed with simple short manipulation tasks (viewpoint modification, exploration or changing parameters of simulation). The main goal of the expert user is to understand and obtain a spatial model of the data based on the current visualization parameters and navigation state.

In contrast the presentation user is typically a company agent, with a technical/commercial background. His or her main characteristics are:

- non expert user
- experienced with using the software during short sessions with an interactive demonstration
- a need for fast interaction metaphors (with sufficient accuracy without causing fatigue, or device acquisition problems)
- no interest in the interaction performance

In general there is a focus on presenting planning scenarios for different tasks and a low level of competence with the software. The main need is for navigation and camera path playback.

2.2 Software Functionalities

Two main components are deduced from the observations: the visualization and interaction functions.

2.2.1 Visualization Aspect

The main goal of 3D visualization is to use the powerful capacity of the visual brain system to interpret multi-variate data. Coherent range color, coherent regions and easily identified primitives are some of the examples of the possibilities opened up by leapfrog3D.

The leapfrog3D software uses a classical polygonal rendering approach based on a client server approach for computing the geometry (points, lines and shaded surfaces). Some sorting algorithms help to provide focus on selected color ranges. Multiple layers and a range of different rendering parameters are used to produce good visual representations. The current focus is on volumetric rendering coupled with parallax motions cue for enhancing the depth perception of the data.

2.2.2 Interaction Aspect

We can identify three types of interaction tasks (based on the taxonomy of bowman [9]):

- **Navigation**: the main focus is a *maneuvering task*: finding a good position to conduct a data analysis from and reiterate with other different viewpoints. Another aspect is the positioning and moving of a 2D plane in the 3D space. In this subtask the motion need not be neglected: it's an important cue for the spatial comprehension of the data.

- **Editing**: Define and estimate a mineral section by a polygonal surface modeling. In the case of LeapFrog3D, this modeling task is complementary to an automatic implicit modeling process (in its initial step). The main manipulated tools are polylines, bezier curves and bezier surfaces with interactive editing of control points (interpolated approach). The accuracy of the positioning has a large influence on the RBF computing step (refine final meshing estimation) used in the leapfrog3D software. The main interest of LeapFrog3D is to assist the user by automatically calculating an **initial 3D estimated volume** of the natural element (e.g gold, balsamite above some threshold, etc).

- **Application Control**: the last aspect covers the control of the visualization parameters. The main components are switching rendering options, displayed object layers, or choosing a tool (one in n).

3 State of The Art

We present in this section a small bibliography related to 3D Interaction and visualization techniques, focusing on manipulation, navigation and system control interaction techniques.

3.1 Visualization

Data representation remains a complex problem in computer human interaction. Scientific Visualization deals with dense and multivariate data that is difficult to represent with a standard desktop interface. Some approaches try to optimize the modeling and rendering cost of the data (parametrization, clustering, multiresolution, impostor, etc.) while other techniques try to provide an alternate way to visualize the data. Research has been conducted on new 3D geometrical representations for the data (isosurface, volume rendering), and on other non-linear data presentation methods: fish eyes view [23], cone tree [49], hyberbolic navigation [34] or focus+context screen [2], volumetric deformation [40]. Many techniques are based on the notion of focus+context: the principle is to isolate a focus area where detailed information is displayed and combine it with a low resolution contextual view kept in the periphery.

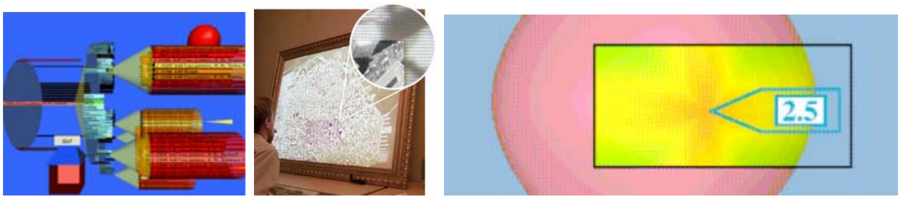

Figure 2: Filtering Visualization Techniques: Cone-Tree [49], focus+context screen [2] and Magic Lens [4].

Bier [4] introduced the concept of a Magic Lens, a filtering view of a data type for providing an alternative representation or an interactive filter (e.g. a snap grid tool). In 1996, Viega [60] extend this approach to 3D graphics applications, and his technique was recently hardware accelerated by [50]. In the context of visualization, the Magic Lens can be used to provided a low resolution view of the data, presenting a specific type of data ([13]) or adding private annotations ([39]).

In this area, not only visual information can be controlled and enhanced (point density, color representation, surface representation) but also interface properties (snap tool, grid tool).

Figure 3: 3D Filtering ([50]): providing another vision of a local area (i.e bones) by keeping the context (i.e. human body).

In this context, Virtual Reality (or more recently Augmented Reality) provides a new way to interact with the data. An immersive approach can provide a better understanding and more intuitive interface for manipulating multidimensional data ([59]). Moreover, Virtual Reality offers the possibility of bridging between a simple pan and zoom viewpoint to a fully immersive navigation inside the data or using multiple viewpoint ([30]). The physical elements of a Virtual Reality system also favours a more natural interaction and enhances collaboration ([17]).

Figure 4: Virtual Reality: 3D Natural interaction and collaboration on the responsive workbench [1]

Using augmented reality can further help to increase the control efficiency by improving the proprioperception or feedthrough manipulation during the interaction. For example, Looser [38] presents an AR tangible interface version of the Magic Lens metaphor enabling the use of natural space to interact with the data.

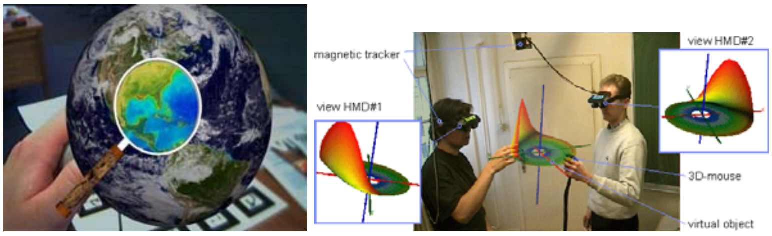

Figure 5: 3D AR Visualization: In left figure, the AR Magic Lens [38] give natural access to views of multiple representations of geographical data. In the right figure, a 3D AR Visualization using the Studierstube framework [54]

3.2 Manipulation

Manipulation is defined as an action to *move* objects in space (translation and/or rotation) after they have been *selected*. A large number of *input devices* have been proposed during the last decades. Some devices are a complete system (with input and output) and/or associated with dedicated *interaction techniques*.

From traditional input devices (like the BAT [61], stylus, glove, elastic devices, or haptic mechanical arm), new devices have been recently proposed (such as the CAT [27] or Cyberstylo©[21]). Recent solutions generally try to enhance the tangible aspect of the device, providing a wireless and lightweight solution, based on a better ergonomic design: there is also a tendency towards the use of vision tracking technology like in the MagicMouse [66]. Readers can refer to [10],[29],[70] for a more formal and detailed description of device taxonomy and properties.

Figure 6: 3D Devices: traditional (top, 3d mouse cyberglove) and new devices (bottom, CAT [27] and Cyberstylo©[21])

Based on these input devices, a classical interaction technique is the "‘virtual-hand"’ approach where the movement of a device (or your real hand) is simply coupled to a 3D cursor. One of the problems with this approach is the limit of human reach, but to this technique, Poupyrev et al. [47] proposed the go-go technique, where a non-linear mapping of the hand/tracker movement is used to access distant object. During an evaluation Bowman and Hodges [11] show the limitations on accuracy of this approach. In contrast, other researchers propose a ray-based approach to object selection and manipulation: including standard [41], cone, aperture [20], and HOMER [11] ray types. Derived indirect selection approaches have also been proposed, like a ray-based hybrid method (Voodoo Dolls [46]) or an Image-Based approach ([45]). Mine et al. [42] use the proprioperception body relationship to coordinate the object interaction and introduces new menu selection techniques.

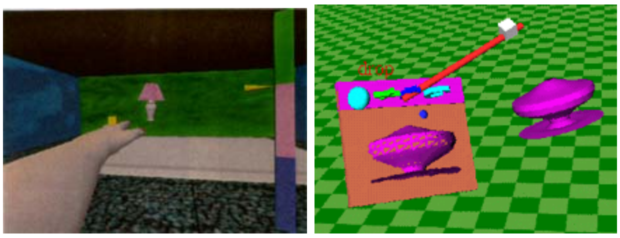

Figure 7: 3D Manipulation Technique: Go-Go [47] and Virtual Tablet [6]

Also, a lot of researchers have tried to use the asymetric division of labour providing by our hands and have introduced two handed interaction techniques: using glove ([16]), tablet ([6], [15], [37], [55]) or with two devices ([67]). Also, the multiple input properties offer by the hand have been studied by researchers such as Grossman et. al. [26], proposing a 3D multifingered interface.

To overcome the limited usability of 3D devices, some interesting work has been developed using constraint or non-linear mapping with traditional 2D devices: adding snap-dragging [3], gravity properties ([56]), and a close relationship to the task at hand ([36])).

Finally, multimodal approaches have been proposed combining gesture and speech recognition in a "‘put-that-there"’ approach ([7]).

3.3 Navigation

The navigation task consists in modifying the actual user viewpoint and can be classified into three categories: *exploration* (with no specific target), *search* (going to a specific goal) or *maneuvering* (to reach a specific position for accomplishing a task).

Ware [62] has introduced a large number of techniques like "flying", "‘eyeball-in-hand"’ or "‘scene-in-hand"’. Pausch et al. [43] introduces the concept of the World-In-Miniature (WIM) where a handheld 3D reduced view of the environment can be directly manipulated to navigate through the scene. Stoev [57] proposes different interaction techniques based on multiple view manipulation with a tangible palet. Finally, Zeleznik [69] proposes a laser approach to translate directly to the area of the selected position.

Hinckley [28] developed one of the first two-hand tangible interface for 3D navigation for neurosurgical visualization. The system used two 6 degree of freedom (DOF) tracked physical props (a head dolls and a 2D plane). Based on the asymmetric properties of hand coordination the user can easily position a 2D slice and navigate inside a virtual brain coupled with the tangible doll head. This is a specific example of the Tangible User Interface approach developed by Hiroshi Ishii at the MIT Media Lab.

Figure 8: Tangible Interface for Navigation: Passive Props [28] and Cubic Mouse [22].

Other tangible user interfaces for visualization input include the Cubic Mouse [22], a 6DOF tracked physical cube with three rods (crossing perpendiculary each face) and control buttons. This two-hand device offers the unique ability to control the scene data (using a "scene-in-hand" metaphor) with the possibilities to move 2D data slices with the rods.

More recently, Billinghurst et al. [5] have developed the Magic Book transitional interface: this allows user to have multiple representative spaces and naturally navigation between them, such as transitioning smoothly between and augmented reality and immersive virtual reality view of data.

3.4 System Control

The system control task consists of modifying the status of an interaction mode or parameters of the system (e.g. the color range of 3D Mining Measurements). We can distinguish mainly four interaction modes ([9]): graphical menus, voice commands, gestural interaction, and tools.

Since this task is common on a desktop interface, a lot of input metaphors have been reused in the context of the WIMP. But the extra requirements of 3D applications have lead to the development of new menu metaphors: such as the pie menu [18], ring menu [35], hemispheric menu [64], C&C Cube [24], Tulip [12], 3D Widgets [14] or ToolFinger [63]. Mine et al. [42] shows that the frame of reference plays a major role during object manipulation, and proposes a body-related menu like applied in [44].

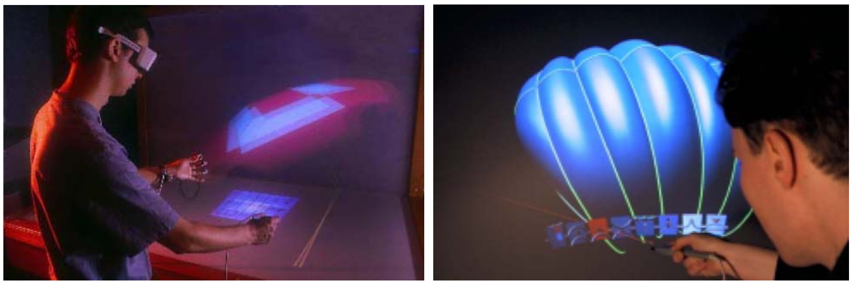

Figure 9: 3D Menu Selection: C&C Cube [24] and Hemispheric Menu [64]

Although voice and gesture may seem the most intuitive technique, they remain difficult to control (requiring a learning stage, robustess problem). In contrast, the use of a physical tool for changing and control an application is becoming popular recently based on the notion of tangible user interface, such as in the Metadesk [58] or ToolStone [48].

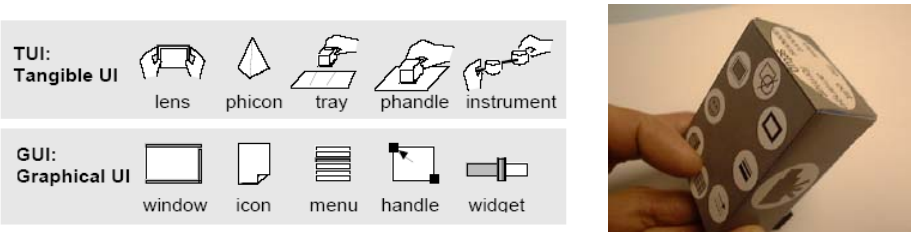

Figure 10: Tangible Interface: Phicons principle [58] and ToolStone prototype [48]

3.5 Modeling and Editing

This task relates to the creative process of modeling, editing or annotating 3D surfaces or volumes[2].

3-Draw [51] is one of the first 3D VR tools based on the manipulation of two hand-held sensors to directly work in a 3D modeling space. Holosketch [18] is another early VR modeling tool based on a head-tracked solution with a 3D wand tracker. There is a lot of different work in using 3 dimensional input during the modeling process, such as CavePainting [33], and FreeDrawer [64]. Haptic Feedback can also play a large role during the modeling, for example, virtual clay modeling using a Mechanical Arm device ([19]).

Figure 11: 3D Modeling Tool: FreeDrawer [65] and a 3D Haptic Clay Modeling Tool [19]

Schkolne [53] introduces a glove-based interface and different sketching tools for drawing simple surface shapes in space. Later, he proposes another interface based on a tongue device to enhance the tangible aspect of the creative aspect ([52]). Recent works have also tried to integrate a dedicated tangible input device adapted to specific application domains and move the concept of

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[2] this task can be related also to manipulation: in a different scale, editing a surface is identical to the task of moving a constrained point in space

modeling to the concept of sketching: such as in chemistry [52] or in automotive applications[25].

Different 2D based-techniques have also been proposed using inference rules to constraint and generate the 3D model: SKETCH [68], Teddy [32], with a suggestive interface [31] or silhouette curvature [8]. These tools allow users to rapidly create 3D content using 2D sketched input.

Figure 12: 2D Based-Approach: Teddy [32] software uses a simple inference rule to simply generate curved meshes

4 First Proposals

In this section we introduce several different project ideas based on the observations above and the previous state of the art. Our main approach is develop a low cost solution, that is wireless (unencumbering), and uses embedded smart technology.

4.1 Visualization

MagicLens: A first interesting contribution can be to enhance the LeapFrog3D software with a **focus + context** aspect. The Magic Lens can be used to visualize different morphological geological solutions, such as a different density of the sampling, or data information (mineral density or orientation). Initially a 2D Lens (screen-aligned) could be added to the software, but a 3D Lens (2D Plane or Volumetric) will provide a more interesting interface in this context of full 3D Visualization. In this case, related work like the AR Tangible Magic Lens or Bier's Magic Lens with a two handed interface provide a good implementation guide.

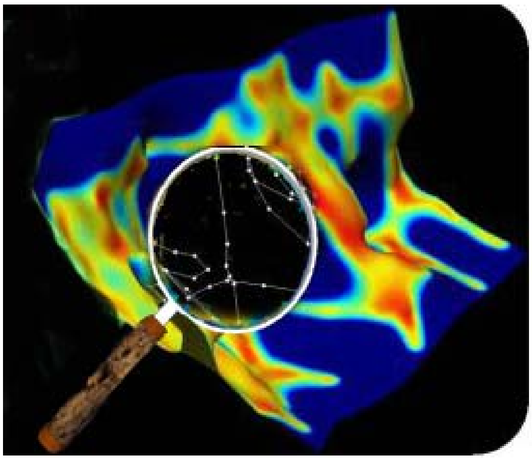

Figure 13: Using MagicLens on Leapfrog3D (photomontage).

3D stereo: The second aspect is to enhance the depth cue. The density, isotropy of the data, or homogeneous shape variety reduces the use of standard approaches to creating depth cues (shadows, relative size, etc.). Parallax motion and depth perception can be a good focus for research. For enhancing depth perception in presentations, use of polarized stereo can be interesting (controlled by a standard graphics card). This passive approach is a good way to provide depth perception of 3D measurements while still remaining low cost. For an expert user, a shutter-glass stereo solution can be used, but eye fatigue can be problematic. In contrast the motion parallax cue can be enhanced by an intuitive interface for rotating the model.

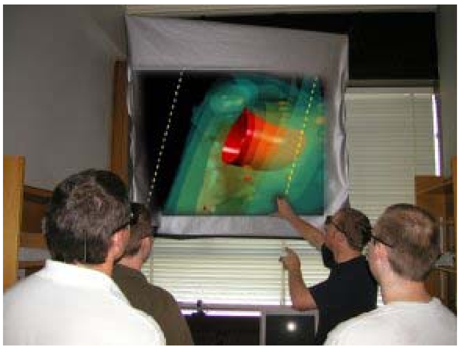

Figure 14: Using 3D Polarized Projection on Leapfrog3D (photomontage).

4.2 Editing

In LeapFrog3D the actual editing is realized by point by point modeling for defining curves. Closed curves are used for defining the Bezier Surface. This step can be largely improved by a better depth perception, but the most interesting aspect is to reduce the reliance on accurate and difficult point by point modeling by replacing it with a more intuitive approach.

For this, a **sketching approach** complemented by an automatic bezier surface definition could be a good choice. The user can draw some rough curves and the program could estimate the closest bezier curve (by inferences rules). Later, he or she can refine this result by using a mouse or other accurate editing tool.

2D sketching: The first solution could be based on **2D sketching on a tabletPC**: the tabletPC (or a plain graphic tablet) is a more intuitive tool for drawing, sketching and modeling than the mouse. The low visual properties of the tabletPC can be overcome when coupled with another high quality screen for the visualization.

Figure 15: Sketching on TabletPC: use a stylus to draw the surface (photomontage).

3D sketching: A second approach could be a glove-based **3D sketching tool** like that proposed by Schkolne (without any parametric estimation). Unfortunately the cost of the glove restricts the widespread use of a system like this. However we propose a lost cost solution based on the ARToolKit computer vision tracking library: A simple marker can be positioned on the back of the userŠs hand. Simple hand movement can then be used to design and draw virtual lines line. Since the task doesn't need good repeatability, or a high level of accuracy (and few DOF), a one handed tracker could be a simple and efficient solution. The position of the tracker could also be moved to the fingers for better accuracy and control.

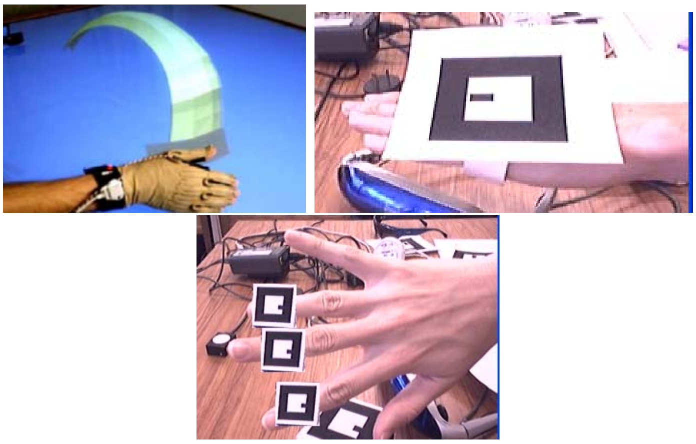

Figure 16: Glove and 3D low cost AR sketching device (based on ARToolKit technology)

Simple movement patterns like a horizontal or vertical gesture can be employed. With these gestures a user can sketch not only a 3D surface but also the volume represented by the 3D flow field.

Figure 17: 3D sketching: the user can not only define 2D shapes but also create 3D curve shapes based on a meshing extrapolation between the 3D flow field.

A last solution can be a more tangible modeling approach like the tape drawing method proposed in [25].

4.3 Navigation

The navigation task, mainly a maneuvering task, solves the need to find a satisfactory viewpoint for analyzing the data: motion parallax can also play a dominant role during this stage. The consistent focus on the data scene encourages the use of a "‘scene-in-hand"’ approach (an AR or VR solution can be envisaged). In this context the manipulated parameters are translation/rotation, choice of center of rotation (local CS), or zooming factor (like that described in [22]).

A good first solution could be an absolute isotonic device like the CubicMouse [22]. This tangible tool provides a simple mapping between the data and a physical interface. The tool also has hardware sliders providing a simple interface for 2D plan manipulation (slice view). An interesting solution is to imagine the design of a new CubicMouse based on a computer vision-tracking

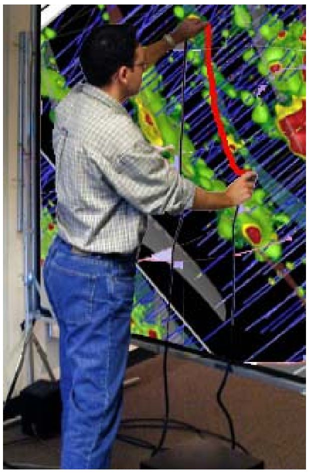

Figure 18: Tape Drawing: curve editing with two 6DOF tracker with LeapFrog3D (photomontage).

and incorporating wireless button. Multiple markers on the cube faces, with a transparent slider can provide a robust 6D tracking solution. A clutch mechanism can be also realized with a pressure approach or a classical switch button.

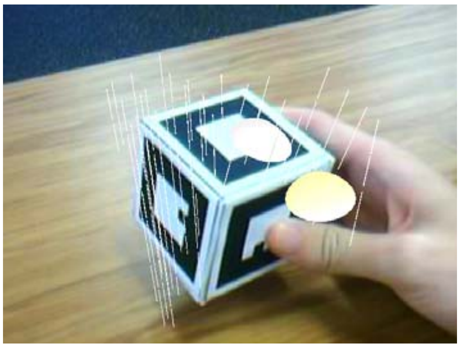

Figure 19: 3D AR Cubic Mouse with 3D Mining Data.

This tool could be used during presentation (fast and efficient) or a short working session. The intuitiveness of this solution is still limited by user fatigue, anthropomorphic constraint (wrist rotation) or limited accuracy. Therefore, an isometric device like a SpaceBall could be an efficient interesting choice for the geologist. Otherwise, we can envision the design of a new low cost isometric desktop device dedicated to expert user. We can combine for example a proprietary low cost inertial tracking technology with pressure technology to create a simple cube-mouse device.

A final area for exploration is the use of desktop haptic input. Companies such as Sensable Technologies (http://www.sensable.com/) now manufacture relatively cost effective 6 DOF force feedback devices. These devices provide stylus like input and accurate point forces. A tool such as this could be a good device for prolonged data exploration and rapid navigation.

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