LeviTABLE: Electromagnetic Topographical Display

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ABSTRACT
This paper describes the design of LeviTABLE, an electro-magnetic controlled topographical display device. The electromagnets control the movement and displacement of an array of vertical rods. The height of these rods represents individual points of elevation in a landscape.

We describe the iterative design and implementation of LeviTABLE, discuss design issues and suggest further research directions and applications.

Keywords
Electro-magnetism, topography, display, interface, haptic, actuation.

INTRODUCTION
Current Geographic Information Systems (GIS) combine hardware, software, people-power and vast amounts of data to create, analyze and compile highly detailed layered renderings of locations. These 3D renderings are generally displayed on flat 2D computer screens, a process that would seem to undermine intuitive 3-dimensional analysis. The display device presented here aims to provide an easily reconfigurable physical rendering of GIS topographical data. Such a device presents information in a way that directly appeals to our intuitive understanding of the physical world, where we are strongly influenced by things that we can actually see and feel [1]. Additionally, this form of display device can be straightforwardly "read" and understood by both people and machines, as the actual physical configuration of the device is tightly aligned to the digital state of the systems it represents [4].

BACKGROUND
Topographical and bathymetric data are two of the most extensively used types of scientific data, as exemplified by their application for a wide variety of scientific, practical and artistic purposes. In general, topographical data have traditionally been presented using contoured maps, whereby contours are used to represent specific elevations. Digital elevation data/models, compiled by processing square-grid arrays of terrain heights, have greatly advanced both the analysis and display of topographical data. GIS technology in turn, uses this information in conjunction with non-topographical data to create complex representations of local features such as environmental damage or population density.

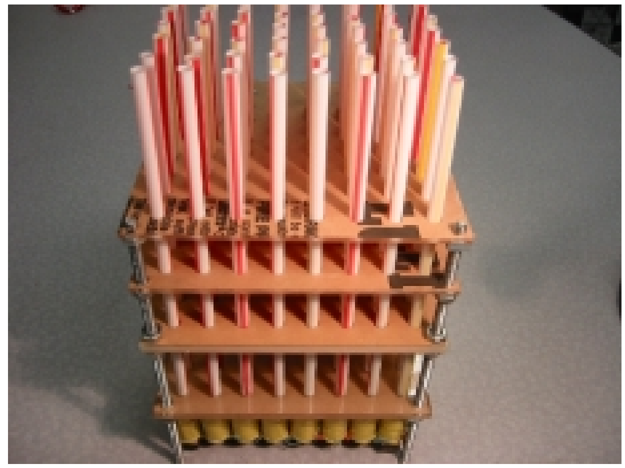

Figure 1: LeviTABLE Topographical Display Prototype

Such representations, created by software packages such as SURFACE III[7], GRASS[6] and ANUDEM[5], are largely presented on computer screens or other 2D flat displays. In contrast, Illuminating Clay[3] is a novel system that involves the projection of landscape related data onto a malleable, reconfigurable 3-dimensional surface. However, this physical surface cannot be manipulated directly and automatically into fixed positions representing specific input data.

Physical models of topographic data appeal more to users' intuitive understanding of the physical arrangement and scope of the landscape being modeled. However, the construction of accurate physical models can often be quite laborious and time-consuming. In the Illuminating Clay system, the user must manipulate a clay topographic surface by hand. The material is easily reconfigurable, but pinpoint precision is difficult to achieve. Prototyping tools such as 3D printers can be used to precisely output three-dimensional plastic models from CAD programs but the manufacturing process often takes many hours or days for larger models. Such a device could be used to create a physical model from topographic data, but once printed, the model would not be reconfigurable.

Arrays of vertical pins appear to be a common arrangement for creating computer controlled topographies. The High Density Tactile Display[2] provides one example of the challenge of precise actuation of topography using pins. Here, an array of 100 pins can be individually adjusted by a large system of powerful linear actuators. This system was designed for creating high-resolution (less than 1.0mm) tactile outputs within an area of several inches, but its implementation could theoretically be scaled up to encompass larger scale applications such as topography.

Application

The LeviTABLE device is designed as a system for computer-controlled actuation of a topographic surface. It aims to allow users to quickly create models of existing real-world topographies from numeric data collected in the field. It also allows users to make topographic changes without painstakingly adjusting physical models by hand.

The LeviTABLE can operate in a number of different modes. The rods can be used alone, to provide a low-resolution simple interpretation of elevation data, or they can be draped with stretchable fabric to provide a more accentuated display. In addition, further information can be projected vertically onto, or horizontally through the device to add supplementary information to the display. The device can be used either to display data points at a singular moment in time, or it can be dynamically transformed to represent changes in input variables (levels of erosion, vegetation growth etc.) over time.

Mechanics and Design of LeviTABLE

The actuation platform consists of a 6.5" square grid of 64 electromagnets. Custom electronics drive these magnets bi-directionally, making it possible to set the polarity and strength of each magnet's field, as well as turn individual magnets off entirely. This hardware was originally designed as part of a system called WeeGee, which moves magnetic objects two-dimensionally on a horizontal surface. However, the potential for using such an array of magnets to actuate vertical motion led us to adapt the system for topographical modeling.

Figure 2: The vertical rods and embedded magnets

In the LeviTABLE, we use the array of electromagnets to create attractive or repulsive magnetic fields that vertically move an array of magnetic rods. A layered acrylic grid-like structure built above the electromagnets holds an 8 x 8 grid of vertically oriented 8" long plastic tubes (drinking straws), each with a small but powerful neodymium magnet attached to one end [Figure 2]. Switching the polarity of the underlying electromagnets allows the system to levitate individual rods 1-1.5" above the top of the electromagnets. Theoretically (though not yet implemented), varying the field strength of the electromagnets through pulse-width-modulation would allow each rod to be levitated to any height between 0-1.5". In practice, however, the interference of the magnetic fields of the neodymium magnets in the rods tends to make this kind of precise actuation almost impossible. For this reason, rods that are not being levitated are held down to the top of the electromagnets by setting the underlying electromagnet to an attractive field.

Previous designs of the system involved embedding magnets in a stretchable cloth membrane, as well as using paper lantern type collapsible pillars with magnets embedded in their structure. Unfortunately, the interference of the magnetic fields of the powerful neodymium magnets proved too difficult to control in these arrangements. An extension of Earnshaw's theorum, proves that an unconstrained permanent magnet cannot be made to levitate stably in a static magnetic field. Therefore it was necessary to build a mechanism that allowed vertical movement of the magnets, but constrained the unstable horizontal movement caused by the repulsion of the magnets by the electromagnets field.

We experimented with hollow aluminum rods, containing wooden dowels that were supported and elevated by small magnets. Ultimately, we decided to use plastic straws, as they were light and flexible but heavier than paper and less resistive than aluminum.

CONCLUSION

LeviTABLE represents a first prototype for an electromagnetic topographical display. The current working model is relatively minimal in scope, in that the rods can be individually displaced and subsequently returned to their original position, but positioning the rods according to actual topographical data input has not yet been implemented. Initial experimentation with various fabrics has also not thus far yielded a suitably stretchy material for placing on top of the rods.

From our experimentation, several features need to be refined in further iterations of the project. Stronger supports are required for sustaining and stretching a pliable material over the rods. Further work is also required on reducing interference from adjacent magnets and for ensuring the accuracy of the display output. Ultimately, building a more refined LeviTABLE system may require the use of stronger and more precise linear actuators, rather than normal electromagnets.

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