The Physical – Virtual Nexus

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Abstract
Our interest is in the transformation of data between virtual and physical forms. Recent advances in 3D printing makes it easy to produce a physical 3D model from a virtual model. However, there are many undiscovered and unexplored opportunities and issues in this form of human computer interaction. We contribute two projects which have explored different aspects of this space.

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Physicalization of data, tangible interfaces, 3D printing

ACM Classification Keywords
H.5.2. Information interfaces and presentation, user interfaces.

Introduction
There are well-understood cognitive advantages of representing data in physical forms. For example, mathematics teachers have long used ‘manipulatives’ to aid in the teaching of mathematics. While computers hold vast quantities of data the most common form of outputting this data for humans is to display or print it as a 2D image. The viewing angle of an image can be changed, however it is still a 2D image.

Various alternatives have been explored including 3D virtual environments and data gloves. But none of these provide the simple, yet effective representation of

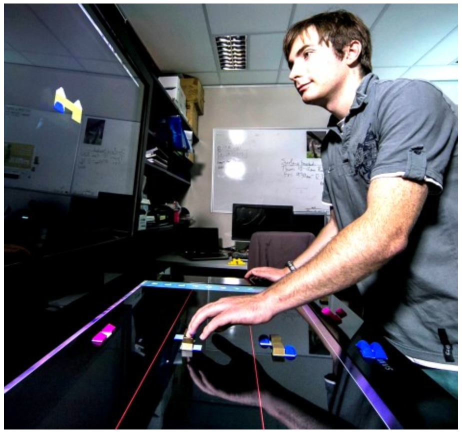


Fig 1. Tangible-Tango: creating a 3D model with smaller tangible units.

a physical model. As an example, because of the limitations of virtual environments it is still common practice for architects to make physical models of building designs.

Based on our previous work in the areas of tangible interaction and building information systems we have been exploring the physical-virtual representation of data. We contribute two projects. The first explored how 3D virtual and physical objects could be constructed by progressively constructing the virtual model with 3D printed physical representations. The second created a physical model of a sound snippet.

Tangible-Tango

Tangible-Tango enables users to fabricate new tangibles and their equivalent 3D virtual models. Users build new models by iteratively creating and assembling physical models. Each physical model has an associated virtual model. The new models, both virtual and tangible, can be iteratively re-used in the system.

The main interaction with the virtual world is a PixelSense table. Physical and virtual models are associated via fiduciary markers on the physical models that are sensed through the table surface.

Users start by making models of small component parts. Currently we start with a virtual model created in a tool such as Google SketchUp (http://www.sketchup.com/), however a physical object could be scanned to create a virtual model. The virtual model is then 3D printed, tagged and associated with its virtual counterpart (Fig 2).

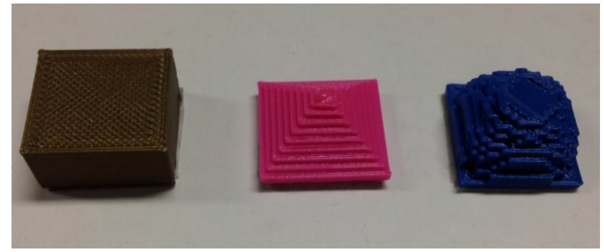
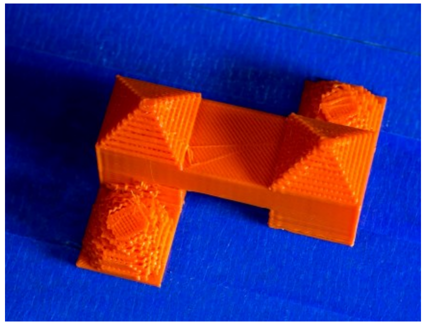


Fig 2. Basic tangible blocks, cuboid (2x2x1cm), pyramid and dome

Users place these components on the tabletop to create a new more complex model. The new models can be printed, tagged and reused in the system. Thus progressively larger and more complex models are constructed.

We approach the 'stacking problem' by providing 3 levels on the table. A tangible placed on a lower level is outlined on the level above so that the user can easily align tangibles on higher levels. This approach to stacking has the advantage of easy construction of unsupported bridges or cantilevers, but the obvious disadvantage of artificial levels.

Our user study suggested a high level of engagement and enjoyment. Furthermore the two architects who participated saw great potential in this type of mixed physical and virtual modeling.



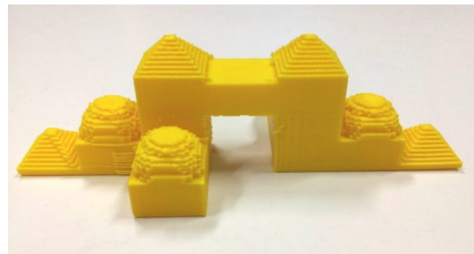


Fig 3. Complex model progressive construction a) 3 level model made from basic components in Fig 2 b) larger model extending model a)

Touch the Sound

In this project a sound clip is rendered as a physical representation. This work is closely related to [2] where the sound is translated into a cylindrical object and [3] where a sound clip is used to personalize jewelry.

With this prototype a sound clip is first translated into a spectrogram which can be visualized (and therefore printed) in 3D. The frequency and amplitude of the sound are respectively mapped to the Y and Z coordinates of the model while the X coordinate represents time. After appropriate transformations the spectrogram is translated into a STL file for 3D printing.

The raw form of the spectrogram is not printable so various transformations were explored to make a model that retains the essence of the original spectrogram but is printable.

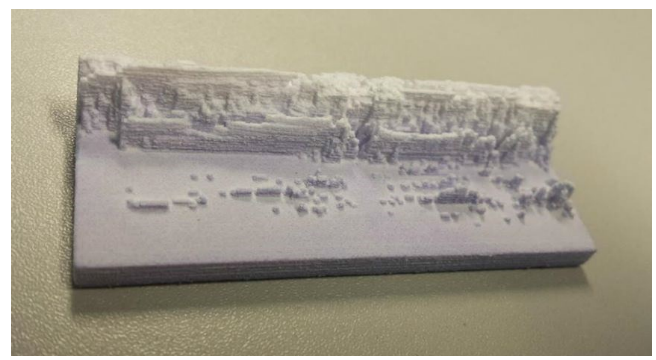


Fig 4. Printed sound clip with moving average smoothing.

Discussion

Our interest lies mainly in making physical objects virtual and virtual data physical. And then using the physical objects to manipulate the virtual world. There are multiple challenges in this.

Making simple physical-virtual mappings of blocks such as we did in Tangible-tango is achievable by starting with either source. However complex physical objects are still a challenge. Sensing the physical blocks to use them as input to the virtual world still has many constraints. Many projects use cameras for sensing tangibles – we are not enthusiastic about cameras because of occlusion problems and setup restraints. Tabletops are a natural interaction space, however sensing stacked objects is an open challenge.

Converting abstract data to physical form requires many decisions to be made about the form it is to take. We are only beginning to scratch the surface of this problem. Clearly our, or other, physical rendering of sound clips has very little resemblance to the sound. There is much more data in the sound that we could consider such as the tone of voice. Regardless of the mapping we found that the user study participants immediately assigned the meaning to the object and were keen to take the 3D print away with them as a memento. Similarly the participants in the tangible-tango study all chose to take their constructions away. Some of these artifacts are still sitting on people's desks – more than a year later in the case of the Tangible-Tango study.

We believe that there is much to explore in this exciting field, including but not limited to, how to make abstract data such as sound meaningfully physical.

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[3] http://www.makoojewels.com/