Dirty Tangible Interfaces — A New Design Concept To Control Computers With True Grit

Figure 1. The ancestor of a Dirty Tangible Interface.

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Abstract

Dirty Tangible Interfaces (DIRTI) are a new concept in interface design that forgoes the dogma of repeatability in favor of a richer and more complex experience, constantly evolving, never reversible, and infinitely modifiable. We will discuss the design principles and early studies of DIRTIs, outline application domains in creation, play, and education. and describe one existing prototype interface realizing the DIRTI principles built with low-cost commodity hardware and kitchenware: a granular or liquid interaction material placed in a glass dish tracked for its relief and dynamic changes applied to it by the user(s). We briefly describe the use of the existing dynamic interface for expressive audio–graphic or music performance and fast intuitive 3D scene authoring.

Author Keywords

Tangible interface; Non-standard interaction; Design-driven; Musical sound synthesis;

ACM Classification Keywords

H.5.2. User Interfaces. H.5.5. Sound and Music Computing

bag of grains
sandbox
airflow
fur
cloud of dust
hologram
mirage
halo of light
invisible form
liquid in suspension
inflated pocket
swarm of flies
leaves

Table 1. Ideas circumscribing the space of possibilities.

Introduction

Should one always manipulate numerous and varied complex data in the same manner as we approach a WIMP (windows, icons, menus, pointer) interface? In this article, we propose to explore an interface principle that would allow a user to interact with complex high-dimensional datasets. We envision to control complexity using a natural gestural palette and with interactions stimulating the senses. In the manner of a hand caressing fur, the apprehension of the complexity is aiming to be corporal, integrating multiple levels of precision/approximation.

We voluntarily distance our concept from precise but sterile interfaces that separate the controller from the controlled object, but rather have the interface adapt itself to it, leading to a protean, contextual interface on which the users can get their hands dirty…

These aims are embodied in the design concept of *Dirty Tangible Interfaces* (DIRTI), for which we present design studies and one concrete implementation of an interface with several applications, that will be introduced in the second half of the article and that is the subject of a separate demo submission.

Dirty Tangible Interfaces (DIRTI) belong to a new generation of complex input devices that take advantage of the finest changes of the environment they are analyzing.

This generation of user interfaces (UI) is especially far from the traditional keyboard, mouse, joystick or even graphics tablet that all rely on the boolean and/or continuous sensing of a small number of buttons or potentiometers.

In particular, we call *Dirty Tangible Interface* a tangible user interface that bears the following features:

- The interaction is tangible and embodied using the full surface of the hands, giving rich tactile feedback through the complex physical properties of the interaction material.
- The return to its neutral position is artificial, in the sense that it is only achieved when the user decides so (i.e. via the software that grabs the information from the interface).
- The interface is constantly evolving, and changes that happen, as little as they may be, are not reversible. Only a discretization by the tracking software could reduce the variations, and artificially enable more discrete changes.
- The interface is infinitely customizable by choosing a different interaction material, e.g. grains, liquid, balls.

The resulting natural gestures in a physical medium can be performed in congruence with cognition and emotions since they do not involve the burden of indirect representations and devices such as mouse-based WIMP interfaces. Whole body interaction, by focusing on expressive and sensible components of gesture (movement quality, energy, fluidity, etc.), promote new modes of interaction in which expressiveness is better conveyed and exploited. Last, surfaces for multi-touch interaction, despite being tactile, do not offer the malleability of fluid, or extensible, or granular, or gaseous media that can support affective or emotional interactions such as massage, expressive contact or caress.

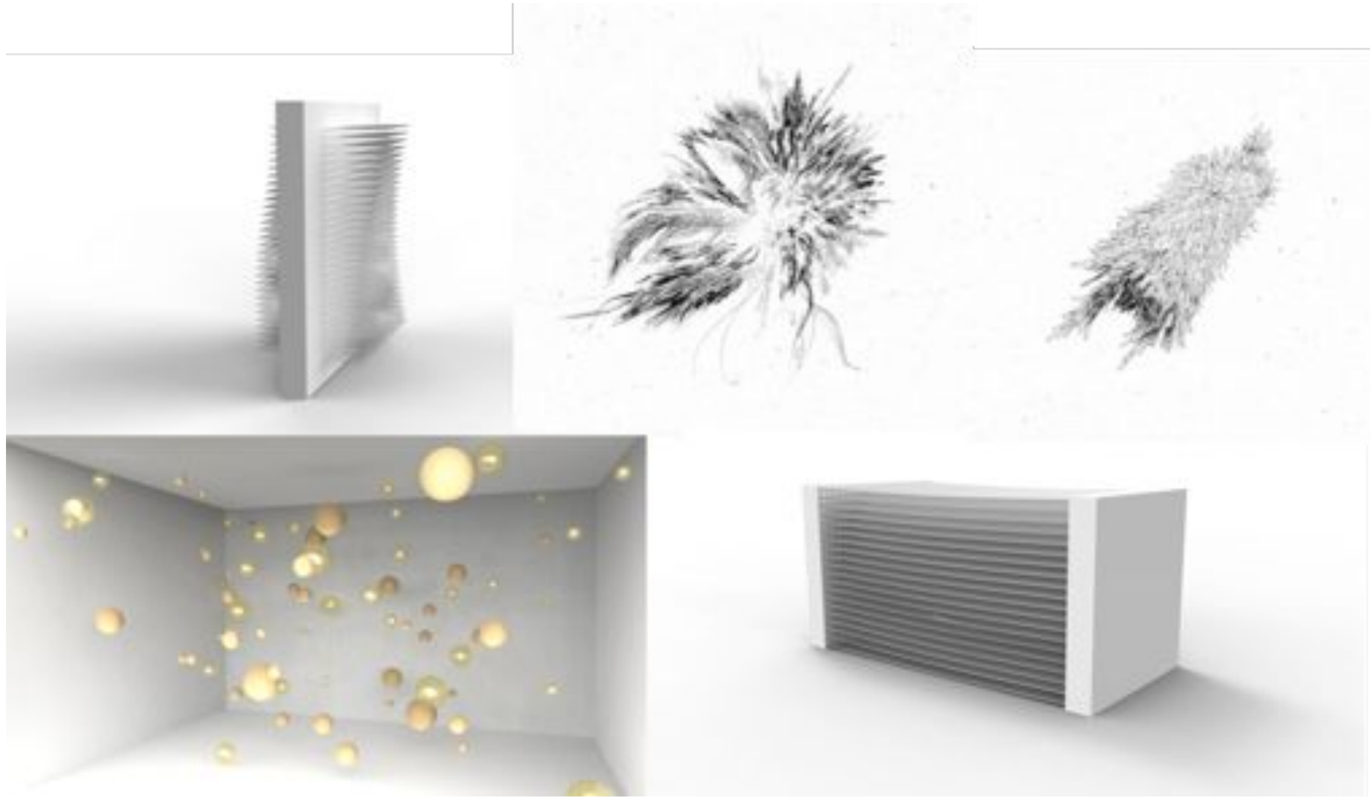

Figure 2. Design studies for the concept of DIRTI.

Figure 3. More or less dirty interaction materials.

Table 1 and figure 2 show early design keywords and studies for the concept. Figure 4 gives a diagram showing the domains in creation, play, and education where dirty tangible interfaces could be applicable.

We implement the DIRTI principle in a prototype interface, which is briefly explained in the third section, based on granular or liquid interaction material placed in a glass dish (see figure 3), the image of which is captured by a commodity USB-camera and translated into a 3D depth image. The prototype interface serves two concrete applications introduced in the fourth and fifth sections: first, an audio–graphic performance instrument where the interaction with the interface controls musical sound synthesis and generates related, visual behaviors on screen, and, second, a terrain editor for the easy and intuitive creation of virtual worlds. These applications can be seen in the accompanying example videos at http://smallab.org/dirti.

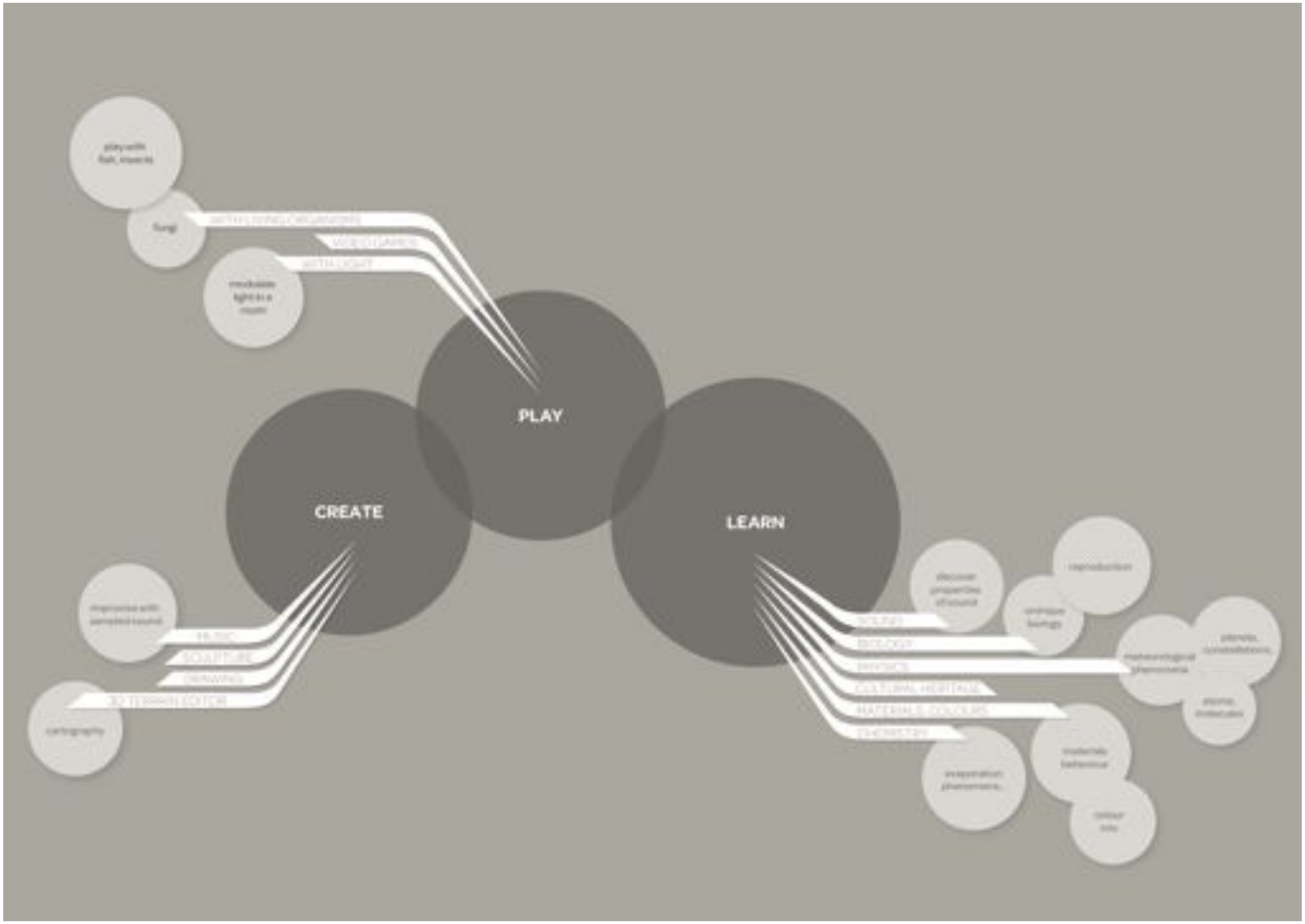

Figure 4. Application domains for DIRTI

Related Work

SandScape[1] [1], [2] is a tangible interface for designing and understanding landscapes and drainage aspects of them through a variety of computational simulations using sand. Users view these simulations as they are projected on the surface of a sand model that represents the terrain. The users can alter the form of the landscape model by manipulating sand while seeing the resultant effects of computational analysis generated and projected on the surface of sand in real-time. Other sand or granule-based tangible interfaces are described in [3][4][5].

The *Relief*[2] [6], [7] and *Recompose*[3] [8] interfaces are actuated tabletop displays, which render and animate three-dimensional shapes with a malleable surface. They allow users to experience and form digital models like geographical terrain in an intuitive manner. The tabletop surface is actuated by an array of motorized pins. Each pin can be addressed individually and senses user input like pulling and pushing.

While our first prototype, when used with sand, strongly resembles these existing interfaces, the guiding principles differ radically: The above interfaces are neither aimed at expressivity, nor made for fast embodied interaction as for musical performance, and the precise (re)configuration of the interface is here the aim, contrary to our *dirty* principle. Also, they use expensive (Laser scanning) or custom-built sensor technology, contrary to our use of commodity web-cams and kitchen glassware.

[1] http://tangible.media.mit.edu/project/sandscape
[2] http://tangible.media.mit.edu/project.php?recid=132
[3] http://tangible.media.mit.edu/project/recompose

The *Splash Controller* organic UI [9] is closer to our concept, detecting manipulation of water in a gaming context. The only slightly *dirty* musical interfaces are *PebbleBox* and *CrumbleBag* [10]. Those examples of a granular interaction paradigm are based on the analysis of the sounds resulting from the manipulation of physical grains of arbitrary material. This analysis extracts parameters as grain rate, grain amplitude and grain density, that are then used to control the granulation of sound samples in real-time. This approach shows a way of linking the haptic sensation and the control of granular sounds. However, this interface focuses on the interaction sound and forgoes to extract information from the configuration of the material.

Prototype

The prototype interface, see figures 6 and 7, consists of a dark box containing a video camera, a semi-transparent glass dish, surrounded by optional LED lights to perform in darker conditions, and containing the interaction material. Several kinds of interaction materials can be used: dry grains (plastic granulate, tapioca grains, peas, marbles), plastic balls, water with ink(s), ice cream, soft chocolate... depending on the desired expressivity, precision/randomness ratio, and inertia of movement wanted. Movement and density of material in the dish are captured from below by a camera placed underneath in order to obtain a gray scale image of the interaction material. This image is then converted by the analysis software into a 3D depth image that controls the specific application, as described in the following

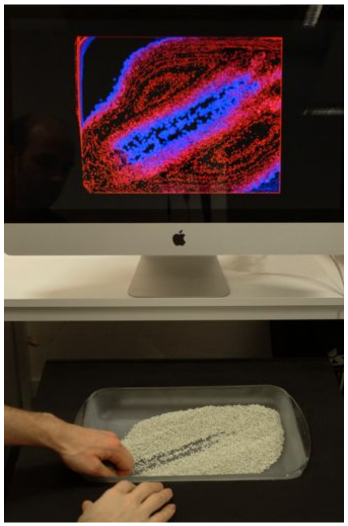

Figure 5. DIRTI detection example

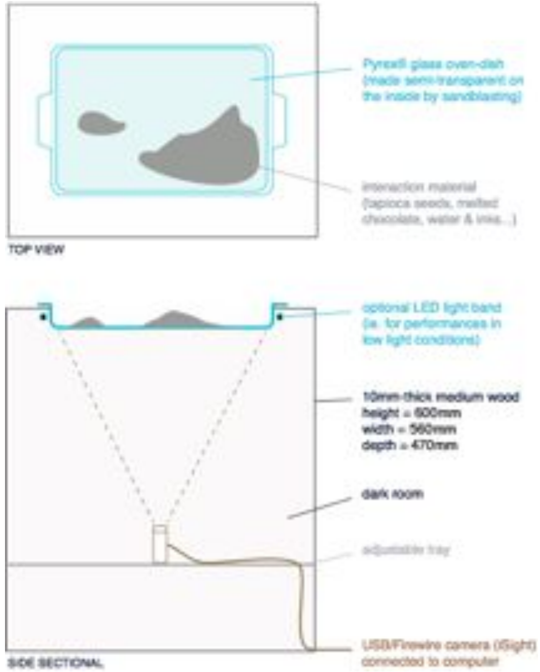

Figure 6. DIRTI hardware prototype schema

Figure 7. DIRTI prototype, open

Detection and Analysis

The grayscale camera image is the source of detection of various parameters:

- density of interaction material
- motion, quantity of movement applied to it
- colors

Based on the grayscale image, n levels of contours of iso-luminance blobs are estimated in the image, where n is a parameter that determines the depth resolution of the analysis, usually set to 20. These contours are then interpreted as a 3D relief of the material: each subsequent level is assigned a depth coordinate, which is a simple and sufficiently precise way to estimate the density and thus the height of the interaction material (see figure 5). However, for dynamic gestural control, our approach is to detect where there is movement in the material. Therefore, movement detection was implemented that assigns a depth coordinate relative to the speed of movement in each part of the image. More details on the tracking algorithm can be found in [15].

Profiles

Both, the depth of the movement analysis, and the depth derived from the background image, are then interpreted as *profiles*, i.e. 2D fields carrying a parameter value, that are in the musical sound synthesis application applied as *activation profiles* to a sound process [11].

Visualization

There are two visualization algorithms, helping in developing the interface, and analyzing the interaction modes. First, the visualization of a 3D image derived from the blobs' assigned depth allows to see the relief of the interaction material. See figures 5 and 9 for examples of the 3D visualization:.

The second visualization includes the points corresponding to active sound segments for our application of musical sound synthesis based on corpus-based concatenative synthesis. It includes feedback of the points’ activation: Quantity of movement is mapped to the size of the point, the background grayscale level is mapped to inverse color saturation, i.e. light background is dark green, dark background gives light green. See figure 8 and the accompanying video for an example.

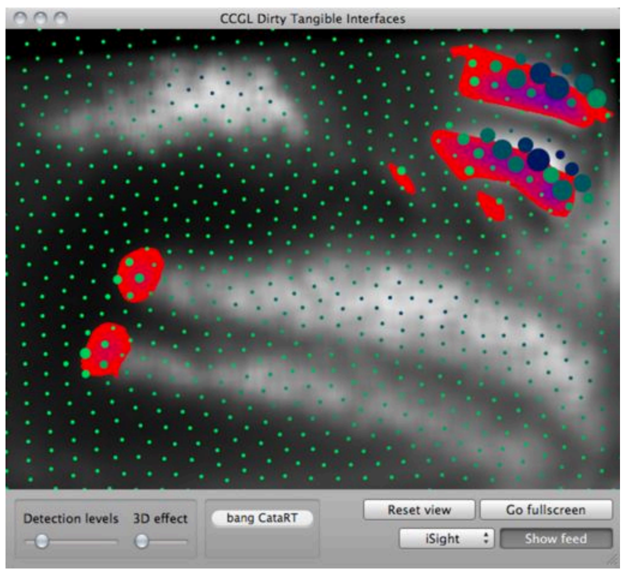

Figure 8. Screenshot of audio activation visualization.

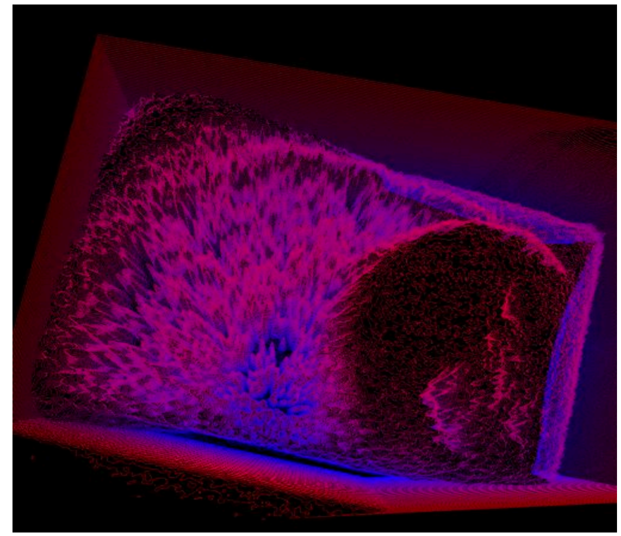

Figure 9. Screenshot of 3D visualization

Application to Audio–Graphic Synthesis

Audio

The audio process is based on corpus-based concatenative synthesis (CBCS) [12][14] as implemented in the CataRT system[4]. CBCS makes it possible to create sound by selecting segments of a large database of pre-recorded audio (the corpus) by giving a target position in a space where each segment is placed according to its sonic character in terms of audio descriptors, which are characteristics extracted from the source sounds such as pitch, loudness, and brilliance, or higher level meta-data attributed to them.

[4] http://imtr.ircam.fr/index.php/CataRT

Figure 10. Screenshot of ***Dirti Traces*** graphical interpretation.

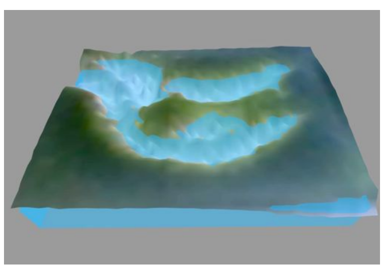

Figure 11. Screenshot of DIRTI Terrain Editor (see **http://vimeo.com/37313858**)

For Dirty Tangible Interfaces, we project the corpus onto the 2D interaction surface by choosing two descriptors as its axes. Each segment then has a 2D coordinate and can be visualized as a point on the detection visualization (see figure 8).

To play the segment associated to a point, we determine if it lies within a blob, in which case the segment is triggered (if it is not already playing). The depth of the containing blob is mapped to the playback gain, so that fast movements play loud, slow movements play softly.

The background profile can be mapped to a sound transformation parameter. In our experiments, we obtained musically interesting subtle effects by mapping the background to a little amount of transposition randomization. This means that at the beginning, with a thick layer of material, sounds play untransposed, but when digging deeper and exposing the bottom of the dish, chorusing effects can be deliberately produced for specific sound segments only.

Optimizing the Interaction Space

While a direct projection of the high-dimensional descriptor space to the low-dimensional navigation space has the advantage of conserving the meaningful descriptors as axes (e.g. linear note pitch to the right, rising spectral centroid upwards), sometimes the navigation space is not optimally exploited, since some regions of it stay empty, while other regions contain a high density of points that are thus hard to access individually. Much of the interaction surface can remain unexploited.

Therefore, we apply the distribution algorithm *Unispring* [13] that spreads the points out using iterative Delaunay triangulation and a mass–spring model, while keeping similar sounding points close together. The results of the algorithm can be seen in figure 8.

Graphics

Several projects of graphical interpretation of the DIRTI interaction are under work. One of them, *Dirti Traces* (see Figure 10), consists of tracking the blobs and using them to represent traces of the movements that get eroded and displaced through time, symbolizing the attack, sustain and decay of the sounds produced by the interaction.

For the future, a graphical feedback similar to that of the *Parametropophonics*[5] audio–graphic, parametric 3D models (formerly *Swirls*[6]) is planned. Here, the audio descriptors for each segment determine the expression of a parametric 3D shape, and their activation will animate parts of the parameters, or interpolate between models.

Application to Terrain Editing

The second application, *Dirti Terrain Editor* (see figure 11), is useful in the domain of creation of virtual 3D worlds, e.g. for simulation, video games, installation, or cinema.

The terrain editor makes use of the density of the interaction material in the dish to edit a 3D terrain on screen, allowing the performer to sculpt mountains, islands, lakes and paths with DIRTI, possibly augmenting the speed of virtual worlds' creation.

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[5] see http://www.smallab.org/dirti/

[6] see http://vimeo.com/21339248 and http://smallab.org/swirls

Figure 12. Design study for future concert and installation version of the interface.

Figure 13. Mockup of DIRTI Tablets

Future Evolution of the Interface

For public interactive installations or audio–visual live performances, we envision a larger concert version of the interface, where a group of visitors could interact with an audio–visual installation or two to four musicians could perform live.

Taking the concept even further, *DIRTI Tablets* is another hardware realization of the interface currently in development, where portability makes the interface accessible to a larger audience: We would use the camera of a Tablet PC such as the iPad with fiber optics and lenses to track the interaction with the granular material, placed in a single piece of hardware that also holds the tablet in place. The latter then serves as a screen for visual feedback and control of parameters for the many possible creative or pedagogical applications.

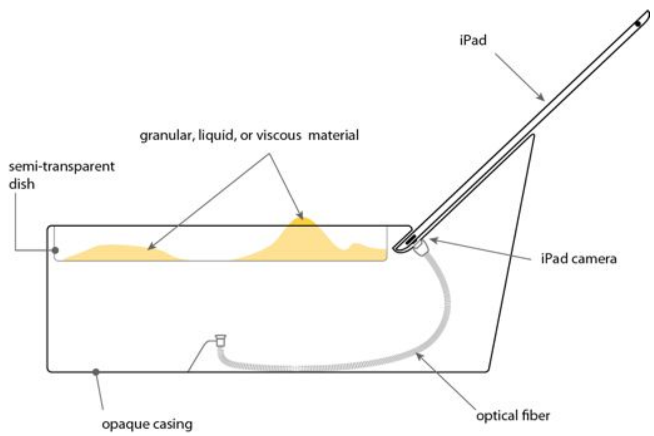

Figure 14. Technical diagram of DIRTI Tablets hardware.

Conclusion

DIRTI is a successful example of design-driven approach in HCI, where the concept comes first, and only after it is well defined and circumscribed are methods and technologies to realize it researched and developed. For the concept of dirty tangible interfaces, this led to a promising first realization that combines a very sensual and playful approach to interaction with inherent collaborative use, all being based on low cost commodity hardware.

The simple approach of converting luminosity to 3D relief, while less precise than complicated techniques like Laser scanning, is sufficient for meaningful and satisfying interaction. The relief, and the dynamic changes applied to it by the user(s), can be interpreted in many ways to control a wide range of applications. We saw the example of directly translating the relief into 3D terrain for fast maps editing by designers of video games.

In the audio–graphic music performance application, both the relief and real-time changes were interpreted as activation profiles to drive corpus-based, concatenative sound synthesis. As can be seen in the videos at http://www.smallab.org/dirti/, dynamic and expressive musical play is possible, matching the dynamics of the manipulation of the interaction material. Thanks to the mapping of the space of sound characteristics to the interaction space, timbral evolutions can be purposefully controlled.

The interface is also suitable for control of graphical synthesis, a kind of real-time painting where one can manipulate many graphical elements at a time, a task that cannot be accomplished through current tactile interfaces, be it pen tablets or multi-touch surfaces.

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