Animafluid: A Dynamic Liquid Interface

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Abstract
In this paper the authors describe a new tangible liquid interface based on ferromagnetic fluid. Our interface combines properties of both liquid and magnetism in a single interface which allows the user to directly interact with the liquid interface. Our dynamic liquid interface, which we call Animafluid, uses the physical qualities of ferromagnetic fluids in combination with pressure sensors, microcontrollers for real-time interaction that combines both physical input and output. Our implementation is different from existing ferrofluid interventions and projects that harness magnetic liquid properties of ferromagnetic fluids in the sense that it adds tangibility of radical atoms design methodology to ferromagnetic fluids, thereby changing the scope of interaction with the ferromagnetic fluid in a drastic manner.

Author Keywords
Tangible Interface; Ferrofluid; Dynamic Liquid Interface; Radical Atoms; Programmable Materiality

ACM Classification Keywords
H.5.2. Information interfaces and Presentation; User Interfaces

Introduction
Ferromagnetic liquid is a material that has magnetic and liquid properties. Ferromagnetic fluids have been used in a variety of different ways in the field of fluid

dynamics. Our implementation imparts tangibility to the liquid interface thus providing the design features of "Radical Atoms", which envisions human interactions with dynamic materials in a computationally configurable manner [5].

Vision

The vision of our interaction derived from two metaphors of nature, namely magnetism and water. Water is shapeless and formless. It essentially adopts shape and form. The mechanical properties of liquids are used in hydraulics for fluid control circuitry, pumps, turbines, and a variety of other engineering modules. Liquids as interfaces are difficult to handle because it is difficult to control them because of fluid properties. The second metaphor that provided vision for our interaction is magnetism. Magnetism is characterized by force, attraction, push and pull. More importantly, magnetism is a rich metaphor for animation and responsiveness under force fields. In our interaction we aimed to combine properties of both water and magnetism. Magnetism imparts control and responsiveness to the liquid interaction and makes it more programmable as a material.

Ferrofluid

Ferrofluid is a colloidal suspension of very small ferromagnetic particles in a non-magnetic carrier fluid like oil. The two most salient aspects of ferrofluid are its responsiveness and its range of interactions. Unlike hard materials like wood or plastic, it is not inert. It responds sharply to magnetic field; hence, under the influence of electromagnetic field, the ferrofluid exhibits sharp, almost animated, responsiveness. Secondly, the range of interactions that are possible with ferrofluids is quite diverse. For example, rotation of ferromagnetic fluids under electromagnetic influence [6] demonstrates one extreme instance of how this material could be manipulated.

Prior Work

Our work is informed by prior work done on electromagnets-based interfaces and ferromagnetic fluids.

SnOil

SnOil [1] is a low powered ferromagnetic fluid based interface that uses electromagnets to actuate ferromagnetic fluid interaction. SnOil utilizes ferromagnetic fluid's sensitivity to magnetic fields to actuate fluid shape and movement. The SnOil essentially has two components. The first component is a container for the ferromagnetic fluids. The second component is an electromagnets grid that sits below the ferromagnetic fluid container. The magnetic grid is controlled by microcontrollers for actuating magnetic field transformations that control the ferromagnetic fluids. SnOil interface exemplifies a dynamic liquid based interface that could be programmatically controlled.

Sensetable

Sensetable [2] is a tangible user interface that allows interactions with solid objects by using capacitive technology on an electromagnetic grid table for localizing and detecting objects. Sensetable provides example of how ferromagnetic interactions could be used in object localization and detection.

Liquid Interfaces

"Liquid Interfaces" by Mixed Reality Lab [3] Singapore is a tangible liquid interface. It is essentially a capacitive touch technology that allows the user to interact with ferromagnetic fluid to produce 3D form responses or musical sculptures.

Work on ferrofluids

The above listed projects directly influenced our design methodology. In addition, we also took into account a diverse range of material properties of ferromagnetic fluids: ferromagnetic fluid have been used to control microchip pump and valve [3]; Magnetic field could be used to rotate floating drops of magnetic fluid [6]; ferrofluid seals are used for sealing in industrial processes, loudspeakers, inertial dampers; and ferrofluids are used as sensors and transducers [4]. The diverse range of interactions provided the motivation for using ferrofluids as a programmable materiality.

System Structure

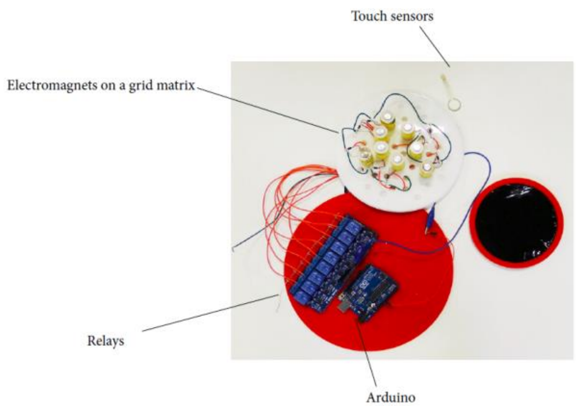

Figure 1. Components of the system

The system has four layers. The first layer, or top layer, has the ferromagnetic fluid in a plastic covered by a thin plastic film. This layer is exposed for human tangible interaction. In the second layer, we have pressure sensors which are placed directly below the ferromagnetic fluid layer. The third layer comprises electromagnets in a circular grid. Finally, the fourth layer has the microcontroller and relays that control the electromagnets.

We used a thin plastic film to envelope the top of acrylic container which contains the ferromagnetic fluid. Initially, we used silicone-based pouches that contained the ferromagnetic fluid. However, we found that silicone was not as responsive as we intended it to be, partially because of the low strength of the electromagnets. We chose thin plastic film to cover the ferromagnetic fluid surface because of its responsiveness and its property of sealing the surfaces in an effective manner.

The acrylic structure that holds the ferromagnetic fluid interface was designed in Rhinoceros 3D and was cut into parts by a laser cutter. We measured the height of each component that was to be placed inside the structure. Then we cut acrylic layers and glued them in concentric circular shapes to create a circular pyramid like structure to contain electromagnets, controllers and pressure sensor.

There are many ways to detect touch points; we chose to rely on pressure sensors. Our touch system works by placing the sensors on a rigid platform right above the array of magnets and directly below the ferrofluid dish. These sensors detect change in the magnetic field near the ferromagnetic liquid, which in turn causes a change in the liquid density and affects the sensors' readings. To avoid false readings we used a simple calibration mechanism. When the application first loads each electromagnet is turned on for a certain amount of time allowing all sensors to average their readings. These average values are saved and later used as reference to detect actual interactions and avoid false readings.

The system is controlled by the ATMega328 microcontroller with an Arduino Bootloader. The system communicates with a computer through a serial interface. Eight, individually controlled, electromagnets are used to move the ferromagnetic fluid. Each electromagnet uses 5 Watts (25 V, 200 mA), which is provided by an external power supply. A diode in an antiparallel configuration is added to each electromagnet to prevent back EMF that can damage the circuit. The digital pins of the microcontroller are used to switch the relays, which turned electromagnets on and off. A relay module comprising 8 relays is used (Kootek 8 Channel DC 5V Relay Module) to operate the switches.

A force sensitive resistor (FSR, Interlink electronics, Pat #402) is used in our set-up to sense finger touch. The FSR is placed in series with a 100-kOhm resistor, thus making a voltage divider. The analog-to-digital converter of the microcontroller senses the output voltage.

Arduino IDE is used to program Arduino Bootloader and the devices connected to it. There are two variations of the programming module. The first variation turns the electromagnets on and off in a sequence, one at a time. The second variation activates two different magnets based on the touch sensor. The user can decide which variation to run by providing commands through the serial port.

Interactions

We have devised two main interactions for our dynamic liquid interface.

Figure 2. Programmed interface.

1) Programmed Interface & Automatic play

The goal of the first interaction is to show translation of programming input into 3D ferrofluid form changes. For this interaction we remove the plastic film from the ferrofluid dish. Our input activates one electromagnet, one at a time, on the electromagnet grid. This results in a pulsating magnetic field that moves from one spatial point to another, i.e. where electromagnets are placed. When the electromagnet becomes magnetized, the ferrofluid accumulation concentrates along magnetic field lines, creating a spatial bump. The end result of this interaction is pulsating occurrence and disappearance of ferrofluid bumps, moving from point to another in the ferrofluid dish. This interaction is an example of a visual interface for music or sound or programmed channel. It translates input pulse into a visual interface for music or sound input. Aesthetically, one instance of such an interaction is translation of one form into another, for example sound into liquid form.

Figure 3. Ferrofluid touch-based tangible interface.

2) Tangible interface

In the second interaction ferrofluid is covered by a thin plastic film. It is a tangible interaction which allows the user to touch the composite material of ferrofluid and plastic film. The user touch activates the pressure sensor on an electromagnet below the ferrofluid dish and triggers magnetization of another electromagnet, which in turn results in a corresponding ferrofluid bump. This interaction produces an output in the same material which takes in an input; hence, it is essentially an interface that combines both physical input and output.

Discussion

Our interface interactions demonstrate two distinct instances of our programmed materiality. The second instance particularly focuses on the properties and characteristics of the material that we have envisioned through demonstration of our instances. Our material is a composite tangible interface that combines the properties of both magnetism and water. In addition, its physical properties are also derived from the secondary material that provides the touch interface— in our case plastic wrap— for our implementation. We experimented with a variety of materials for the touch surface material. We created various casts of silicone in which we injected ferrofluid. We found that the silicone showed different properties than that of plastic film. For instance, silicone exhibited surface depression and elevation when it was subjected to electromagnetic field. The response was less remarkable than that of plastic film bumps; however, it was a different type of material response. While plastic film exhibited behavior change in a form of ferrofluid bumps, the silicone material showed smoother and more localized bumps. We also combined silicone with ferrofluid by mixing them together to create a new material. We found that the hybrid material was still responsive to electromagnetic field. From this we deduced that the modality of our tangible interface— i.e. rotation, retraction, depression, elevation, protraction, vibration or expansion— is tied to the kind of material we use for the interface. In other words, the type of interaction or modality could be changed by using a different material within the same set up.

Future Direction

In the future, we propose creating a synthetic memory material that combines ferrofluids and silicone or a material with silicone-like properties. This material could be programmed using pressure and touch sensors to conform to input form of an object. For instance, when someone is holding it in one's hand, it takes on the shape of the hand contours based on touch pressure points. One important aspect of such a synthetic material could be memory. By remembering shapes this material could be used for a wide variety of ergonomic materials. As we have demonstrated that ferrofluid-based materials could be easily programmed with a microcontroller. Such materialwill have a broad range of properties that could be triggered using microcontroller signals.

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References

[1] Cheok, Adrian David, et al. "Mixed reality lab Singapore: a genealogy of lab projects employing the blue sky innovation research methodology." Proceedings of the ACM 2011 conference on Computer supported cooperative work. ACM, 2011.

[2] Frey, Martin. "SnOil-A Physical Display Based on Ferrofluid." (2004).

[3] Hartshorne, Herb, Christopher J. Backhouse, and William E. Lee. "Ferrofluid-based microchip pump and valve." Sensors and Actuators B: Chemical 99.2 (2004): 592-600.

[4] Iniewski, Krzysztof, ed. Smart Sensors for Industrial Applications. Vol. 14. CRC PressI Llc, 2013.

[5] Ishii, Hiroshi, et al. "Radical atoms: beyond tangible bits, toward transformable materials." interactions 19.1 (2012): 38-51.

[6] Morozov, K. I., A. Engel, and A. V. Lebedev. "Shape transformations in rotating ferrofluid drops." EPL (Europhysics Letters) 58.2 (2002): 229.

[7] Patten, James, et al. "Sensetable: a wireless object tracking platform for tangible user interfaces." Proceedings of the SIGCHI conference on Human factors in computing systems. ACM, 2001.

[8] Szydlo, Z., et al. "Magnetic fluid seals-materials, design, application." Problemy Eksploatacji 3 (1998): 309-322.