From meaning to liquid matters

Zelf Koelman, Mark J. de Graaf and Hans J. Leeuw

Eindhoven University of Technology - Department of Industrial Design
Eindhoven, The Netherlands
zelf@zelfkoelman.com, m.j.d.graaf@tue.nl, h.j.leeuw@tue.nl

Abstract

Artists like Sachiko Kodama have demonstrated the aesthetic potential of ferrofluids in unique, visually spectacular installations like the Morpho Towers and Breathing Chao [2]. This paper presents a more systematic approach to ferrofluid manipulation: a vertical display, build under project-name: “Liquid Choreography”, later released as “Ferrolic”. [1]

This Digital FerroFluid Display’s (DFFD) potential rests in visual references to movement of fluids but also living creatures. Specific dynamic and graphical properties that generate a narrative in the form of an animation are displayed in a video [1] that is central to this paper. In order to understand the written descriptions in this paper, it is strongly advised to review this video before reading this paper. Also see figure 1 and figure 2.

In the first part of the paper, the principles of operation of the DFFD are described. Creation of images, transitions between images and fundamental aspects of FF manipulation are presented.

In the second part of the paper, a first attempt to come to a vocabulary for the use of the DFFD as an expressive platform is presented. For this purpose seven different animations were generated and presented to in total five experts in the field of art and design. These experts were interviewed about their personal constructs for the animations. Based on a systematic (thematic) analysis of these interviews, the vocabulary was derived.

Keywords
FerroFluid, display, tangible, content, choreography, liquid, narrative, dynamics, nature, electromagnets, Ferrolic.

Introduction

Motivation

Intrigued by the aesthetics of Sachiko Kodama’s work on ferrofluids [2], people who practice both art and science such as Louis-Philippe Demers [3] and Neri Oxman and work of many students, artists and designers like Marcin Ignac [4] who visualised data in very creative ways, motivated me to turn a long shelved idea on how to shape and move a liquid body into a physical reality.

The value of new and inconceivable embedded in a natural looking appearance - regardless it’s true level of artificiality - is likely to have a natural attractiveness to people. Well known examples are Neri Oxman’s life-size tangible sculptures that are based on microscopic biological physical structures [5] and Harvard’s technology that grows flowers on a nano scale [6]. I believe these new unique technologies are not only carried widely because of their technological uniqueness, but also because their natural appeal; Meaning, their close visual relation to nature itself.

Purpose and Goals

There is a well established body of art-work on FerroFluid. Sachiko Kodama made it well known in the form of liquid sculptures [2]. The opportunities for manipulation of FerroFluid in these sculptures are however limited. In this work we aimed to create a technological platform that allowed for more freedom in manipulating FerroFluid and to develop a vocabulary for the creation of content.
An open research model was applied to get grip on the design process, yet, leave room for innovation. [7]

**Background**

We conceive the majority of digital information through two-dimensional arrays of light-sources, better known as LCD displays; A large number of small light-sources packed densely together because just a few, so called, pixels would have no meaning. Perceived information is generated by multiple formations of many pixels, each with different colours that can produce a (from a humans perspective) infinite amount of combinations.

To make matter understandable, the infinite is reduced to a useful set combinations that we recognise as visuals with meaning. Among clearly observable text, photo and video, this new unreal mini-world on a screen seems to be always in conflict with its own size. Software interfaces try to help us bridge the unnatural gap of it all happening on this small screen using functional methods like scaling, tabs, windows, scrolling, etc.. Eventually, displayed content that refers to real world matter will never be observed as natural as its tangible counterparts.

Tangible means perceptible by touch. It is one property an LCD display can not forward when it is displaying content. For displays, tangibility is a property that does not per se mean that the matter has to be touched to be observed. Examples of displays that use tangible matter are the flip-
disk display [8] that we often see installed on city-busses and The Water logo by Hara Design Institute [9] that systematically displays text in the form of water-droplets floating on hydrophilic fabric. These tangible displays all have a specific characteristic because of their own physical properties. Properties that are visually been observed as true matter. This paper covers specific characteristics that belong to the digital FerroFluid display.

The Digital FerroFluid Display

The DFFD in essence consists of an array of electromagnets behind a container of FF. Every electromagnet can be controlled individually by setting the current through the coil.

With this array of magnets, images can be created and manipulated dynamically. Figure 3 shows how a straight vertical line builds up. In total 5 time frames are shown, one every 500 milliseconds. At the top half of the figure, the black/green screens represents the applied magnetic forces for every pixel. In this example only “on” and “off” is used. A white dot is “on”, at the bottom half of the figure, the actual observed FF (ferrofluid) distribution is shown.

The straight line builds up from the FF reservoir at the bottom of the DFDD. If the same force is applied to all pixels, the line will be thickest at the bottom and get narrower towards the top. The actual density distribution between two adjacent pixels is influenced by several factors: gravity, adjacent magnetic fields, locally available amount of FF and cohesive forces in the FF fluid. The combination of cohesion and gravity cause the broadening towards the bottom of the line.

For a controlled manipulation of FF it is necessary to incorporate these factors. Figure 4 shows an example of a transition between two shapes, the number “3” and the number “4”. In this case, the used algorithm calculates the needed quantity of FF, breaks up the “3” into 3 separate dots on strategic positions and creates an additional FF dot from the reservoir. From these dots the number “4” is created. Notice how the strengths of the magnetic field is not the same for all pixels. It is lower near the bottom and at the pixel at the lower left corner of the “4”. The latter is because this pixel is effectively helped by the neighbouring pixels. Though many ways are possible to achieve this shape transition, this one illustrates the considerations to be made in such a transition.

Towards a vocabulary for FF manipulation

After having the first animations reviewed in a set of exploratory user-tests, it became clear there was an evident difference in appeal for the different animations. It was also hard to communicate the specific values for viewers and maker alike. To further develop this medium it was (and is) necessary to be able to clearly communicate about its specific characteristics.

Expert evaluations

In order to map the specific characteristics, seven animations were made that all contained a mix of specific visual characteristics. The seven animations of the first test-set have been described and labeled in table 2.

These animations were evaluated by in total 5 professionals from the field of arts and design, all with a different background. Table 1 outlines the procedure for the inter-
Next we describe the parts in turn. The participants were individually interviewed. The experimental setup was as following: participants were invited into a closed room and sat next to the interviewer in front of the Digital FerroFluid Display. The interviewees were given a short introduction on the following steps.

<table>
<thead>
<tr>
<th>Part</th>
<th>Average Duration</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>3 minutes</td>
<td>introduction to the study</td>
</tr>
<tr>
<td>II</td>
<td>21 minutes</td>
<td>reviewing 7 animations and answering the primary question</td>
</tr>
<tr>
<td>III</td>
<td>4 minutes</td>
<td>answering secondary question</td>
</tr>
<tr>
<td>IV</td>
<td>2 minutes</td>
<td>debriefing</td>
</tr>
</tbody>
</table>

Table 1. Procedure for interviews series 1.x

Participants were asked to review a sequence of 7 animations that were displayed on the DFFD in random order. In Table 2 these animations are described. The first question to the interviewee was what do you see? which had to be answered for every single animation. This question, as well as the physical setting, was borrowed from the Rorschach test [10]. Descriptions were vocally explained by the participants during their reviewing. There was no particular time constraint for every animation. The participants reaction was recorded during the interviews as written notes.

In the interviews series 1.x, two out of five participants mainly judged the animations on its specific visual characteristics (i.e. leaking, or morphing), two participants mainly judged the animations on its narrative (i.e. A chase of two creatures or 9 am) and one participant judged the animation on both.

After all 7 animations where reviewed by the participant, the second question was to judge the animations again. This time, participants that focused on the visual characteristics were asked to focus on the narrative and vice versa. All participants were able to take both perspectives. Table 3 shows frequently used properties (at least more that twice by different participants) over the two methods of observing and explaining the content.

Observations on narratives

In the interviews, different type of narratives about the animations came forward:

- **Body language**: A direct reference to animalistic or humanistic behaviour. Also called anthropomorphism which is closely related to empathy [11].
- **Written figurative matter**: Translation of meaning through letters that form words and/or trough numbers that form values.
- **Non-written figurative matter**: Direct translation from visual representations to meaning.

Combination of narratives also occurred.

Participants mainly had difficulties to translate animation 5 (pong) and 7 (rain) into its narrative. Further questions revealed that they did not recognise the narrative be-

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pattern</td>
<td>A repeating cycle of: An array (horizontal line) of separate bodies arising from the bottom, moving up and dropping at the top.</td>
</tr>
<tr>
<td>Chase</td>
<td>One body following another, variations in speed and distance</td>
</tr>
<tr>
<td>Clock</td>
<td>Four digits displaying the actual time</td>
</tr>
<tr>
<td>Fountain</td>
<td>FF spraying upwards from a point in the reservoir</td>
</tr>
<tr>
<td>Pong</td>
<td>A game of Pong animated in FF</td>
</tr>
<tr>
<td>Smiley</td>
<td>Different Smileys morphing into each other</td>
</tr>
<tr>
<td>Rain</td>
<td>A continuous cycle of bodies moving upwards from the left and right of the reservoir into a large body at the top of the display and raining down again into the reservoir</td>
</tr>
</tbody>
</table>

Table 2. Seven different animations. The first test-set.

<table>
<thead>
<tr>
<th>Category / Level</th>
<th>Specific visual characteristics</th>
<th>The narrative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Actions</td>
<td>The narrative and/or emotional reference</td>
</tr>
<tr>
<td>Average physical scale</td>
<td>1 to 4 square actuation points</td>
<td>1 to 4 square actuation points</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>Morphing, Leaking, Speeding, Accelerating, Dropping, Moving, Disintegrating</td>
<td>Pattern, Mass, Systematic, Repetitive, Randomness</td>
</tr>
</tbody>
</table>

Table 3. Mapping a vocabulary
cause of lack of detail. The tests showed that, due to the low resolutions of actuation points, a simple combination of very basic distinguishable figurative matter - like dots and lines forming text and numbers - is likely to be successfully translated into meaning. If a dot itself shows specific dynamics, it is judged upon references to animalistic behaviour. A side-conclusion could be that the more physical detail the figurative matter is expected to have, the less likely it is that the narrative is readable.

A living entity Testing the first prototype (one vertical array of magnetic actuators) a thing reveal itself when a sinus wave was applied to the actuators. A FerroFluid drop that got separated from a mass that floated on the bottom, was perceived as a body. Not only a body in physical terms, but like interviews 1.x also turned out: body with a strong relation to a living organism. The current DFFD prototype allows this body to freely move vertical and horizontal over the full width and height of the display.

Participants associated the visual effect of this phenomena to the movement of biological organisms that move through water. They regularly recognised tadpoles, little fish and undefined little creatures. The participants explained to be intrigued by the unknown playful movements. The creatures seemed harmless and evoked the participants to discover them and it was mentioned to be perceived as a pleasant experience.

This visual reference might be the same reason why the artificial FerroFluid bodies, moving through water and forming a tail, are perceived as living creatures. Similarities put forward in several discussions are that the creatures perform a degree of random behaviour, have a third dimension (in contrast to LCD displays), are made of true matter, are explorable into fine detail and share different visual dynamic relations like speeding stretched bodies. Here is an interesting similarity to Disney’s Twelve Basic Principles of Animation; A set of principles of animation introduced by the Disney animators Ollie Johnston and Frank Thomas in their 1981 book The Illusion of Life: Disney Animation.[12] Where it is their goal to produce more realistic animations adhering to the basic laws of physics.

The most discussed principle squash and stretch [12], which gives a better sense of weight and flexibility to a virtual object, happens to be a core property of the digital FerroFluid display since this visual effect is caused by true natural physics itself. The success of these principles and the relation to what is perceived on the DFFD may illuminate an important value of using true (liquid) matter in animating a narrative.

Positioning the DFFD
Though practically everybody that was invited to experience the DFFD was deeply intrigued by it, it is hard to pinpoint a potential natural habitat for it. To shed some light on this matter, at the 2014 International Robotics, Art and Science forum Bal Robotov 2014 in Moscow, Russia, a second round of interviews was done with five experts from five different institutes. They represented the realms of indeed art and science. All had in common that their personal projects, like this one, somehow bridges science, art and technology. These interviews 2.x - inter alia, with Alexander Reben from MIT Media Lab and Louis Philippe Demers from NTU, Singapore - added perspective to these uncertainties. Below some relevant quotes from the interviews.

The experts visions Its basic function is generating a very specific kind of aesthetics. What it is and where it lives highly depends on the kind of content.

“You want to create an aesthetic threat for people. You want to give someone an experience. Show them something interesting and beautiful. And your medium is technology, your medium is digital but the actual piece is definitely an artwork..... It could also be practical; It could be a clock. But it will probably be expensive, heavy and consume a lot of power so... that’s why it’s still art.” (Interview 2.4 - Jonathan Tippett)

In its current state, it’s unique value lies in the specific dynamics that occur during the transition from one state to another, which is also its main function and reason why it is build, regardless the kind of content. This makes it a worthy to be considered “art”.

“The less you make it scripted (it being the animations), the more it is coming to be a thing on it’s own. The more you make an animation that is recognisable, the more it is going to be like a... you name it...” (Interview 2.1 - Louis-Philippe Demers)
Conclusions, Discussion and Future Work

Conclusion

The DFFD, in its current state of development, can be seen as an expressive platform mostly for use in the field of art. Though it is up to the artist to decide about the suitability of the platform for her or his ambitions there are some considerations that can be made to assess this suitability.

The key question is: Does the animation has a narrative? If the answer to this question is NO, the aesthetic qualities of the DFFD is in the same league as for example a lava lamp. If the answer is YES, we propose to distinguish three types of narrative, each opening a different aesthetic perspective. If the narrative has an (1) anthropomorphic character, the lifelike associations people have with the FF animations is expressed very well. It is also possible to have more (2) figurative use, like in the animation of the fountain or the rain. Also in these cases the appreciation for the aesthetic qualities is expected to be high. Finally (3) a simple textual animation like the time flowing in the 4 digit clock animation is generally found intriguing too. The DFFD usually fails when we tried to express more detailed graphical information. The quality is in the dynamic behaviour and certainly not in the high information density of the visualisations.

Discussion

The intersection of science and technology in our opinion is an exciting place to be. With the DFFD we have found a fascinating area with unique aesthetics. Initially the ambition was to find ways to display useful information using FF. The display presented in this work does not offer that practical usability yet. People engaged in art and interactive installations receive it with enthusiasm. As such it offers a new expressive platform. Quoting Janet Murray's three principles from her Inventing the Media framework:

“All things made with electronic bits and computer code belong to a single new medium, the digital medium, with its own unique affordances, designing any single artifact within this new medium is part of the broader collective effort of making meaning through the invention and refinement of digital media conventions, and When we expand the meaning-making conventions that make up human culture, we expand our ability to understand the world and to connect with one another.” (Murray 2011) [13] We hope and believe that the work presented in this paper does contribute to future developments of interactive media.

Especially in the fast growing field of shape changing materials we see potential relevance of this work: The aesthetic qualities found in this work do offer a richer, possibly more humane, perspective on that field, beyond functionality and usability. As Janet Murray states: “we need every possible medium to express our humanity.” (Murray 2003) [14]

The Inventing the Media framework has also been considered for the evaluation of the DFFD. However we feel that the main strength of the display lies in the narrative, whereas Murray’s framework leans more towards higher information densities, which is not a particular strength of the DFFD. That is why we feel it is justified to introduce our own key question about the narrative as the key value of the display.

On a more technical level, we believe that a certain degree of randomness in the flow behaviour of the FF is an essential element of the aesthetics. To a certain degree this randomness is implicit in the material properties of the display. Yet it might be relevant to include this aspect in the development of algorithms for the manipulation of the FF too.

Future Work

Technology To enable the content to be generated and reviewed by a large audience, this platform could open its gates to an endless realm of algorithms, narratives and creative expressions by making it interactive through an online portal.

A third dimension The current design consists of a grid of magnetic actuators. The third dimension is generated by the magnetic arcs that form over the grit. Further research in shaping these arcs could add new visual characteristics.

More efficient magnets The magnetic actuator’s current design is stretched to its physical boundaries. New technologies could reduce energy-consumption and provide smaller actuators.

Acknowledgements

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References