Soft Surface Displays: Exploiting Reflection and Dispersion of Liquids

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Abstract. Screen displays based on front and rear projection have become very popular with the broad availability of video projector technology, ranging from professional high-end down to consumer and home entertainment systems. Traditionally, the screen canvas in such settings is made from solid, reflective material like silver cinema screens or white walls – usually in flat, rectangular format. We propose soft material like flowing or vaporized liquids as an alternative to screen hardware, particularly for display systems that inherently gain from the soft nature of liquids, that need to sustain the possibility to trespass the display, that rely on the randomness of the dynamics of liquid and steam dispersion, and that do not allow for bulky, on site physical screen hardware setups. We first study the physics of reflection and refraction for soft material like fog, vapor and crystal liquids, and argue for the particular characteristics of lighting effects that can only be achieved by this material. We assess the utility of controlled and uncontrolled material propagation for the purpose of displays. Finally we report on a real world experiment involving a 200m^2 fountain screen.

Keywords: ubiquitous display systems, projection technology, fountain displays, fluid displays.

1 Motivation

"*Surfaces dominate the physical world. Every object is confined in space by its surface. Surfaces are pervasive and play a predominant role in human perception of the environment.*" [1] Even though surfaces have become an important issue in ubiquitous display research the main focus lies on planar surfaces. As a matter of fact the common approach of display projections implies a flat, rectangular shape (see Fig. 1 left). This indeed is sufficient for various scenarios of projected displays, such as public advertisement displays, lecture hall displays, home cinema displays, or even displays enabling the office of the future [9], but furthermore several applications for ubiquitous displays are eligible which demand a more flexible screen shape. Benefiting from the visual styles facilitated by different screen shapes, a new level of display perception can be experienced. Examples are the particular highlighting of the shapes of objects subject to presentation, while omitting the usual rectangular screen boundaries, or the accentuation of 3D shaped objects with projected surfaces (see Fig. 1 middle and right).

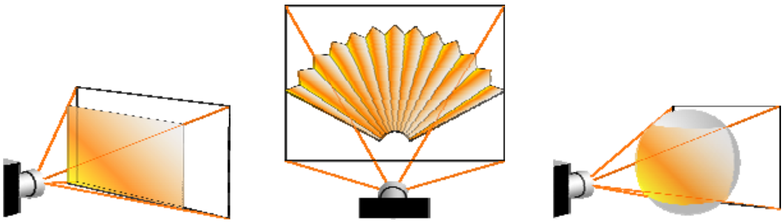
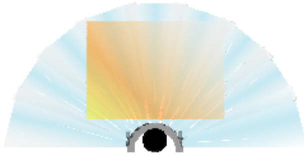
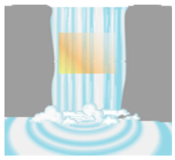


Fig. 1. Front projections: flat, rectangular (left), arbitrary shape (middle), 3D objects(right).

To substantially enhance contemporary projection systems based on solid, flat and mostly rectangular shape, we propose to use soft surface materials as projection screens. Water in its liquid or vaporized state (see Tab. 1) for instance provides sufficient reflection surface, while providing non-flat surface shapes induces by its natural flow or dispersion. The physical characteristics and dynamics of liquids in general suggest the use of soft surface displays in applications demanding artful aesthetics like informative art or peripheral or ambient displays (an "*abstract and aesthetic peripheral displays portraying non-critical information on the periphery of a user's attention.*" [5]), serving a peripheral perception purpose. When it comes to aesthetic impressions flowing and vaporized liquids are predestined for achieving astonishing artful effects. Further considerations supporting the use of liquid or steam based soft surface displays range from the ease of installation, the hardware free setup, the near weightless display material, the possibility to safely trespass the display screen, up until the instant removal and reinstallation of the display surface.

Aside the requirements for softness of the display surface, also the aspect of multitude of display surfaces has become a demanding issue. As for example, Molyneaux and Kortuem [6] argue that the "*… need for more display space has led to a quest for alternative display solutions.*" Continuing this argument, we claim that the "*use of multiple surfaces that already exist in the environment*" [6] must not be limited to indoor spaces. If we manage to adapt to environmental conditions, a broad range of outdoor ad-hoc display setups would be accomplishable. This could be achieved by using fluid displays for instance, enabling projections on dangerous, unreachable or inaccessible ground where the usual projector-to-canvas setup is not possible.

Finally, technological advance promises to enhance projections even onto non-flat surfaces. In [8], Raskar et al. state that "*… projectors are currently undergoing a transformation as they evolve from static output devices to portable, environment-aware, communicating systems. An enhanced projector can determine and respond to the geometry of the display surface...*". Given current progress in projector calibration technology [4][10][7] we claim that it is possible to use both the controlled surfaces, as for example provided by a sprinkler or a fog machine, and the uncontrolled ones, as appearing in nature (waterfalls, geysers, etc.), for projection. Hence it appears also technologically possible to use fluids in liquid state or vaporized (see Tab. 1) as projection surfaces.

	controlled dispersion	uncontrolled dispersion
liquid state		
vaporized		

Tab. 1. Categories of projection surfaces.

2 Reflection and Refraction

Beaming light onto various soft surfaces, some basics concerning the physics of light need to be considered. Recalling from optical physics[2], we know that in order to be seen an object can either emit its own light or it must reflect light. Reflection involves two beams - an incident beam and a reflected beam. A beam of light hitting a given surface is called an incident beam. After the hit this beam bounces off and is now called reflected beam. The angle between the incident beam and the normal equals the angle between the reflected beam and the normal (see Fig. 2 left, $\theta i = \theta r$).

Specular reflection is defined as a sharply defined beam resulting from reflection off a smooth surface. On the contrary, diffuse reflection (see Fig. 2 middle) appears on rough surfaces. The beams of light are reflected in many directions. The angles of incidence and reflection are still equal but the rays appear to be scattered.

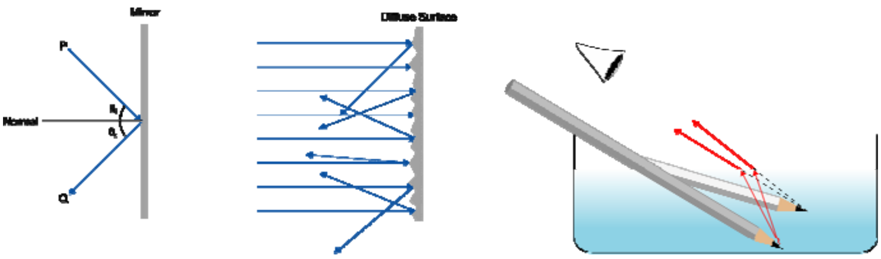


Fig. 2. The angle of incidence equals the angle of reflection (*left*). Diffuse reflection (*middle*). Refraction of light in water (right).

Refraction occurs when the light beam changes its medium; as for example, when light travels through air and then goes through water (see Fig. 2 right). As a matter of fact, the speed of the light beam and its direction changes when entering an optical medium of different density. It depends on the density index of the media if the beam slows down or speeds up. For instance, light slows down about 25% when passing through water and 35% when passing through glass. In the denser medium the light beam moves slower, in the rarer medium the beam moves faster. When light enters a denser medium the beam bends towards the normal - when light enters a rarer medium it is bent away form the normal.

Many materials have a well-characterized refractive index (see Tab. 2). The refractive index of a material is the factor by which the phase velocity of electromagnetic radiation is slowed relative to vacuum. It is usually given the symbol n, and defined for a material by:

$$n = \sqrt{\epsilon_r \mu_r}$$

where ε_r is the material's relative permittivity, and μ_r is its relative permeability. Some of these optical refraction indices are recalled in Table 2.

medium	**n** (at λ=589.3 nm [light])
vacuum	1
helium	1.000036
air	1.0002926
water [ice]	1.31
water [liquid, 20°C]	1.333
ethanol	1.36
glass	1.5 – 1.9
diamond	2.419
carbon dioxide	1.00045

Tab. 2. Optical refraction indices of potential display surfaces.

3 Experiments with Liquid Water Displays

Motivated by the soft surface display capabilities and the technical feasibility we conducted a series of experiments, assessing the suitability of liquids for display surfaces according to the categories in Tab. 1. In a very large experiment setting we focussed on water as the display surface material, partly motivated by the unlimited availability, but partly also as a matter of disposability. While the Tsunami Water Screen [15] builds a display in a cascade of flowing water, we have followed a fountain like approach to build a liquid water display from the ground, by pumping water at high pressure onto a shield plate (see Figures 3.-5. for the installation, and Figure 6 for the achieved projection result). In this setting a 200m^2 water fountain screen was generated and presented to the public in the "*Lange Nacht der Forschung 2005*" event [14] on the campus of the Johannes Kepler University Linz. The installation was built on a platform in the pond of the university campus.

The basic setup (Figure. 4) included a pump water tender that provided the water supply. On the platform in the pond (Figure 4 right), two high pressure water hoses where connected to the shield plate sprinkler device, building the water fountain screen. In this demonstration installation, a live video streams from an indoor smart living installation, together with some background information on the project was presented to the public (Figure 6). The achieved display quality was unexpectedly high and well appreciated by the public audience.

Fig. 3. The scene.

Fig. 4. The setup.

Fig. 5. The testing phase.

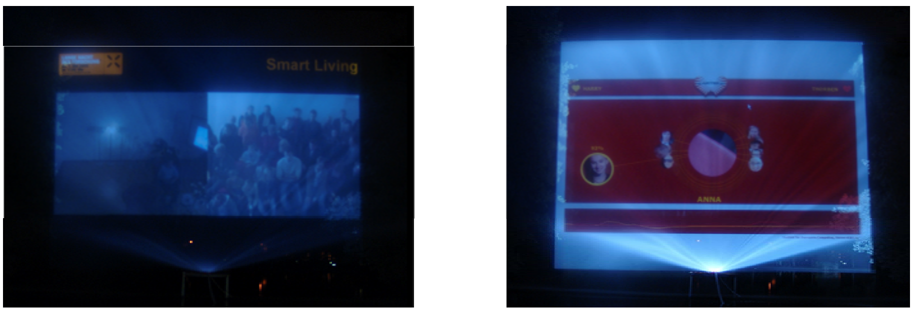


Fig. 6. Display quality achieved for live video stream (left) and desktop information (right).

4 Conlusions

Soft surface display material like flowing or vaporized liquids as an alternative to screen hardware have been proposed, particularly for display systems that inherently gain from the soft nature of the dispersion and diffusion of liquids, steam or fog. Often, for display systems involving users to interact in body with a display, the criterion of being able to safely trespass the screen canvas – which is the case with flowing or vaporized water displays– is essential, precluding any kind of hard and heavy weight display surface material. The physical characteristics and dynamics of liquids in general suggest the use of soft surface displays in applications demanding artful aesthetics like informative art. In such applications, where artful aesthetic impressions are a demanding display property, flowing and vaporized liquids are predestined for achieving astonishing artful effects. Fluid surface display are furthermore often easy to install, can be dynamically switched on and off, by that being physically "built up" and "removed", they involve near weightless display material. In case of water or steam, the display material is even disposable (almost) freely available at large scale.

As a field of future investigation we have looked at fog displays, As opposed to approaches studying the controlled disperson of fog (like e.g. the Moony [12] or the FogScreen [3], [13]), we are interested in studying the random steam diffusion dynamics, and to exploit them for the purpose of peripheral displays.

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