Cloth Displays: Interacting with Drapable Textile Screens

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ABSTRACT
In this paper, we present a user interface for a textile computer display. It allows users to interact in ways that flow from the natural properties of cloth, with an interface that physically conforms to the shape of the object on which a task is performed. While recent work on flexible interfaces has shown promising results, physical properties such as the rigidity of the display remain a barrier to interaction scenarios that are truly physically flexible. We discuss interaction techniques for our cloth user interface, which include gestures such as pinching, draping, stretching and squeezing. Our interaction techniques employ the unique physical characteristics of cloth, including flexibility and shape-taking. We reflect on the system and examine potential directions for future work.

Author Keywords: Textile User Interface, Organic User Interface, Flexible Displays.

ACM Classification Keywords
H5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

General Terms Human Factors

INTRODUCTION
Traditional user interfaces, such as graphical user interfaces (GUIs), are usually designed for surfaces that are rigid and inflexible. Recent work, such as Siftables [8], and commercial products like the Optimus OLED keyboard, design for the use of small and thin displays embedded into appliances. However, physical properties, such as the rigidity of the display, remain a barrier to flexible form factor scenarios. Interactive cloth presents a relatively recent direction in user interface design. In its flexibility and lightness, interactive cloth has the potential to fit organic form factors in ways that provide more flexible and lightweight interactions with objects of different shapes or forms.

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Figure 1. Cloth draped over a cereal box provides an interactive menu to its ingredients in a language of choice.

Rather than enforcing its own shape, cloth takes the shape of underlying objects, allowing it to assume a wide range of forms. Interaction with a piece of cloth draped over an object provides a tight coupling with the object itself. In this paper, we explore how textile displays could be draped over real objects that do not have a display, or that have a form that does not fit traditional displays. As cloth takes the form of an object, affordances provided by the object's shape become part of the available interaction vocabulary. These properties make cloth an ideal interface for interacting with live objects, such as humans.

Physical interactions with, and the properties of, cloth are natural and well understood by users; cloth may be folded, draped, stretched and touched. Interaction styles, such deformations, have logical effects that are easy to comprehend: a piece of cloth grows larger when stretched, and takes the shape of a rigid object when draped over it. This means that a users pre-existing knowledge of the interactive properties of cloth can be of use in developing a cloth interface.

RELATED WORK

Technological Developments

Current research on textile displays, such as Lumalive [12], and Flexible Organic LED displays (FOLED) may provide the back-bone for a future cloth computing device. FOLED displays are thin, light and flexible, and currently provide visual fidelity comparable to a computer display, while having many of the physical characteristics of a thick piece of paper. A review conducted by Sweatman [16] found rapid improvements in the performance of OLED technologies over the past two decades, with decreasing costs. Further work on e-ink, which has seen real commercial release, is another area from which the necessary interface technology may be drawn.

Textiles in Computing

Current research on interactions with physical textiles has largely focused on fabric coloured with thermochromic ink, and has often used the textiles in clothing. Wakita and Shibutani [18] describe a wearable ambient display created with a textile that uses thermochromic ink to change colours based on touch interactions. Berzowska describes her concept of memory rich clothing, by which she means clothing that exhibits its history; in this case, its touch history [2]. These systems evince the universality of textiles and their potential for interactivity in everyday scenarios.

Bergelin discusses using textiles as an interactive surface for a toy known as Spookies [1]. While the first iteration of the Spookies toy uses the textiles to simply cover physical LEDs and buttons, a later version uses woven thermochromic ink coupled with electronics to generate heat and change colours and shadings on the toy programmatically. Similar to Bergelins work, Nack et al. developed small interactive throw pillows [9].

Current textile interfaces largely seek to hide the computing elements of the device and allow users to interact directly with the cloth and objects they envelop. We extend this work by providing a general textile interface that may envelop numerous objects and shapes, rather than a single object.

Paper Interfaces

The Digital Desk system, described by Newman and Wellner [10] was one of the first systems to couple physical paper with graphics projections, blurring the line between virtual and physical, as users interacted with physical paper to perform regular computing tasks. Similar to Digital Desk, in PaperWindows, Holman et al. [7] use standard sheets of paper, augmented with motion-capture markers, to display projected data. This allows for a paper display that can be folded in all three dimensions. The sheets are interacted with using simple hand gestures, such as a rubbing motion used to transfer images from one sheet of paper to another.

Guimbretiere [4] developed systems that closed the loop between digital and physical documents, capturing physical input to annotate and modify associated digital versions of these documents.

Finally, work by Usuda [17] and Schwesig et al. [15] have discussed the use of tactile input, such as folding and bending, to interact with augmented physical paper and paper-like devices. Schwesig et al. describe their Gummi interface as a bendable computer. Made up of sandwiched flexible electronic components, users interact with Gummi by two-dimensional positioning and bending of the interface.

Gestured Interaction

Work on contact gestured interaction often focuses on gestured control of touch sensitive surfaces, such as the Smart-skin system described by Rekimoto [14]. Further work includes Han's on a low-cost multi-touch interface [5]. These systems demonstrate the power of coupling input and output, and use generalized gestures that may be broadly applied to numerous application scenarios.

In [13] Piper, Ratti and Ishii discuss the Illuminating Clay system. This system uses a laser scanner to track the topography of clay on a table and projects an interface directly on the clay. Users interact with the system by shaping and molding the clay, and view the system output on the same. The authors argue that their system provides an improved interface for tasks, such as creating and modifying the topography of a space; they operate directly on the topography through the clay, rather than indirectly through devices such as a mouse or keyboard and CAD software.

IMPLEMENTATION

Our system was implemented by optically tracking retro-reflective points on the cloth and on the users hands, and projecting imagery on the cloth from above, using off-the-shelf hardware and custom software.

Tracking

The hardware used for tracking both our cloth and the user's interaction and gestures consists of two eyebox2 cameras [19]. These provide a stereoscopic image of the interaction area from which three-dimensional tracking data is calculated. The eyebox2 is a 1.3 megapixel video camera fitted with an infrared filter over the lens. In the housing that surrounds the camera lens is a matrix of infrared emitting LEDs.

We developed a stereo vision algorithm for image capture and point recognition in the system. The vision algorithm detects bright clusters within the camera image, each of which is a single reflective square.

The individual points tracked on each camera are then used to calculate the height of each point in space. For the purposes of our work it was necessary that the height be sufficiently accurate to detect changes in the physical shape of the cloth, to differentiate between gestures above and physical contact with the cloth. Our height tracking is accurate to approximately 2cm within a range of 30cm above the work area (50cm by 50cm).

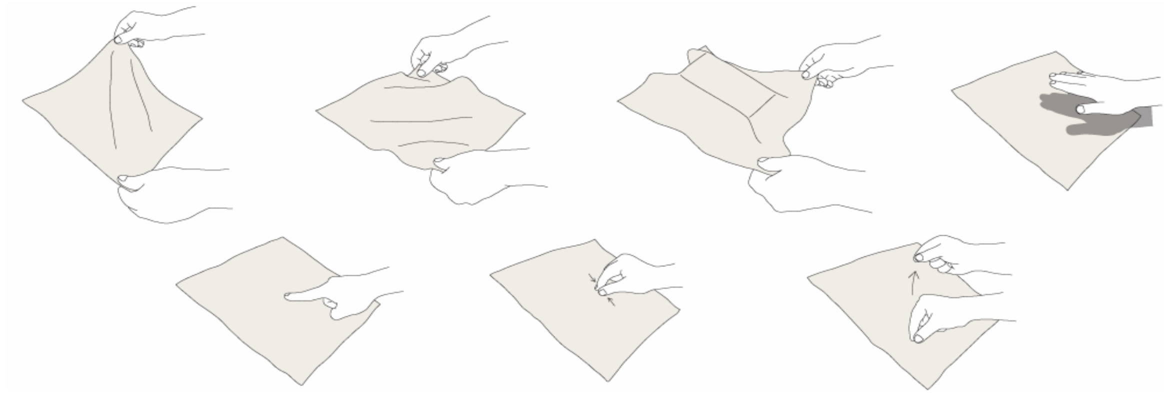

Figure 2: Our generalized set of gestures. Clockwise from upper left: Stretch, squeeze, drape, hover, touch, pinch, and peel.

Projection System and Physics Engine

While our system tracks numerous points on the surface of the cloth, the actual surface is continuous. For this reason, the physics engine models the surface of the cloth and interpolates to determine the position of points between the tracked points. The physics engine itself models the sur-face of the cloth as a series of weighted balls, connected by springs. By varying the mass and the spring constants of nodes, we obtained a model that closely approximated our actual cloth. This model deforms naturally, can fold over it-self, and can be stretched, returning to its original shape once released. This physics engine was also necessary for simulating virtual cloth responses to user actions, such as the pinch and peel gesture. The hardware used for the display system consists of a BENQ DLP projector, operating at a resolution of 1024x768, mounted above the workspace.

The Gesture Engine

The gesture engine operates on data received when a user interacts with the cloth. Since both the physical cloth and the users fingers are augmented with infrared markers, the 3D locations of all interaction elements are known to the system. Based on predefined gesture routines, the gesture engine monitors user interactions and changes the system state as the user interacts with the cloth. These routines are defined as a set of display states, with transitions between these states triggered by specific gestures.

DESIGN

We will now discuss guiding principles for our interaction design. The development of our interaction techniques drew heavily from the principles of Organic and Tangible Inter-faces [6]. Our design principles are as follows:

1. Interactions flow from the cloth metaphor: Users have preexisting ideas about how they interact with cloth, and these should be adhered to as much as possible.

2. Input equals output: Our system should avoid splitting user attention between input device and the display [6].

3. Form follows function: Shape provides valuable information to users as well as system on possible functionalities of the underlying object.

4. Physical or gestural interaction: There are cases where physical touch is not desired, for example, for reasons of hygiene or registration. We therefore included remote gestures, which can be executed while hovering above the cloth.

Gestures

We developed the following six interaction techniques to manipulate information presented on the cloth display:

Stretch: Cloth is stretched from opposing corners, or from two points on the cloth. As a stretch gesture physically in-creases the size of the cloth, this gesture is typically used to zoom or enlarge graphics on the cloth display. The user's region of interest may be defined by the points held by the users when they executed the gesture.

Squeeze: To perform a squeeze, cloth is pushed together from opposing corners, or from two points on the surface of the cloth. The natural counterpoint for the stretch gesture, squeezing the cloth reduces the visible surface area, often reversing the effect of the stretch gesture.

Drape: Here, the cloth is placed over an object, taking the object's shape. In the drape gesture, the cloth becomes aware of the underlying topography of the surface upon which it sits. The cloth display may adapt appropriately to this contextual information, whether by displaying information about the underlying object or adapting the display area in accordance with the available surfaces.

Hover: A finger or hand is held above the surface of the cloth. Such a virtual gesture allows interaction without disturbing the cloth itself, and may be used in situations where touch may not be appropriate or desired due to the situation of the cloth or underlying objects. The hover gesture often precedes a touch gesture, and indicates attention or interest. Hover gestures may elicit additional information about the area beneath the hover (with a fisheye lens for pictures, for example).

Touch: When touching the cloth, pressure is applied to one or more points on the cloth surface. It is detected by sensing the distance of the finger to the cloth. In simple implementations, touch (along with hover) may duplicate the functions of a standard GUI, and act as a mouse click. This allows a cloth interface to include all functionality presented by a standard GUI.

Pinch & Peel: Fingers are pinched together on or above the surface of the cloth. A pinch indicates that the user is grasping information or elements displayed on the surface of the cloth. A pinch may be focusing action, selection, or the physical grasping of graphical objects on the display. A peel gesture follows a pinch, and may be used to rearrange displayed information or elements, or to remove a layer.

APPLICATION SCENARIOS

Our system has been applied in a number of scenarios that are in the realm of in-situ augmented reality. In these scenarios, our cloth computer acts as a thin contextual display interface to interact with other objects.

Medical Imaging. Our first application is in operating rooms. Here, a surgical drape augmented with markers is projected on to display information, such as X-Rays, directly on the topography of the body. Surgeons can interact with scan data over the body by using the hover and peel gestures to navigate layers of imaging information.

Augmented Objects. Fig 1. demonstrates our cloth display as a reusable interactive display for augmenting everyday objects with high-resolution contextual information. After draping the cloth over the object, our camera determines the type of object through pattern matching its contours. The system then projects a graphical interface onto the object. In this example, users browse the contents and origin of the ingredients of a type of cereal directly via the product label.

Interactive Clothing. We also experimented with presenting data on clothing. This is useful for presenting, for example, data about the physiology of a patient, such as blood pressure and heart rate directly onto the body as the patient moves through a hospital setting. The tracking and projection equipment can be mounted on a bed, or, as long the patient stays within a range of up to 2m, be in a fixed location as well.

Textile Windows. Our final application is a low-cost textile version of PaperWindows [7]. Here, the drape is used to interact with otherwise non-interactive pieces of real paper. For example, after draping the cloth over a paper map of a city the map becomes fully searchable. Users can zoom the map by stretching and squeezing the cloth, and use route finding applications by touching locations on the map.

CONCLUSIONS

In this paper, we presented a prototype cloth computing interface. It allows for contextual interaction with a user's environment by draping a physically flexible cloth display over otherwise non-interactive objects. Future systems will require further developments into flexible, LED based display technologies such as Lumalive. We have presented some applications aimed at providing contextual interfaces to everyday objects that are otherwise not augmented with an electronic display, including surgical drapes, product labels and paper maps.

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