SurfaceWare:
Dynamic Tagging for Microsoft Surface

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ABSTRACT

Microsoft Surface is distinguished among commercial multi-touch systems by its ability to interact with tagged objects. In this work, we examine a new class of tagged objects where the tag is dynamic—it changes in response to some sensed variable. As an example, a drinking glass is described which can sense when a refill should be offered. The glass is completely passive, containing no electronic components or moving parts, and works with an unmodified Microsoft Surface.

Keywords

SurfaceWare, Surface, dynamic tags

INTRODUCTION

Microsoft Surface [1] is a multi-touch, tabletop computing system developed and sold by Microsoft Corporation. Unlike most commercial multi-touch systems, it has been specifically designed to allow interaction with tagged objects. It works by shining infrared (IR) light through a diffuser, and watching for reflections via a series of cameras [2]. Surface tags work similarly to bar codes, except that the pattern must be visible in IR.

Many demonstrations have been created showing the utility of tagged objects. For example, Surface has been used to compare merchandise in a retail setting [3]. When tagged products are placed on the tabletop, they are recognized, and appropriate media is displayed. A casual gaming application involves tagged bits of glass that serve as video puzzle pieces [4]. In this case, the identity of the object and its location, rotation, and even flip orientation are utilized in the interaction.

In addition to object identity, location, and orientation, one could imagine that it might be useful to sense other physical parameters of tangible objects on a tabletop. These could range from the obvious (e.g. how hard someone is pushing on a physical button) to the whimsical (e.g. how much is the object being squeezed). In these cases, we would like the information on the tag to change with the physical parameter being measured. We call these *dynamic tags*.

When thinking about interaction design, it is too frequently the case that we focus exclusively on responding to intentional user input. There are many scenarios where it would be more appropriate if the system were able to anticipate user needs and take action without explicit user requests. We refer to this as implicit interaction [5]. This style of interaction depends on an ability to sense what is happening in the environment. This can be accomplished with dynamic tags.

Consider the use of a tabletop computing system such as Surface in a bar or restaurant. Ordering from an electronic menu is an example of an explicit interaction. An implicit interaction might be to sense the fluid level in the drinking glasses (via a dynamic tag), and automatically cause a refill to be offered when beverages are running low. We will examine this particular scenario in depth.

In the proceeding sections, we will show how the optical tagging system of Microsoft Surface readily lends itself to the use of inexpensive dynamic tags that can sense physical quantities. We refer to dynamically tagged objects that are designed to work with Microsoft Surface as *SurfaceWare*. As an example, we present a SurfaceWare drinking glass – a glass which contains no electronics or moving parts, yet allows an unmodified Surface to optically sense the fluid level in the glass.

PRIOR WORK

As noted previously, there is a significant body of work devoted to the use of static tagged objects on Microsoft Surface. (See [1] for examples.) This is hardly surprising, since the system was designed for this application. Earlier examples of tangible interfaces include [6].

Communication with a tagged object is similar in concept to dynamic tagging in that both convey information from the object to the system. However, in the case of the dynamic tag, the relatively small amounts of data allow us to create extremely simple transmission mechanisms with minimal hardware. For example, a well-known Surface demo shows placing a tagged camera on the table, and the photos "flowing out" of it [1]. In this case, the static tag is used to identify the presence of the camera, which the system then connects to via an RF link. We do not consider this an example of dynamic tagging.

ForceTile [7] is a tangible interface device consisting of an elastic body that contains two layers of markers that move relative to each other when pressing on the device. By tracking the markers with cameras underneath a rear-projected table, the applied forces (including twist) can be measured, and used in an interaction. We would consider this an example of a dynamic tag.

It is worth noting two earlier systems which can directly or indirectly sense fluid level. The MediaCup [8] had an accelerometer which allowed it to measure tilt. Fluid level can be inferred from this data presuming that the glass is emptied by tilting. This method fails when a straw is used. The MediaCup contained a significant number of electronic components, and needed to be regularly recharged.

iGlassware [9] was an instrumented drinking glass which used passive RFID technology to measure and report fluid levels. Power for the glass was provided wirelessly via a reader in the table. Fluid level was measured via the capacitance between an electrode on the outer surface of the glass and the fluid itself. While exhibiting many desirable qualities, this system was vulnerable to error if drink contents adhered to the side of the glass, as was the case with certain stout beers. (In the beer industry, the frothy residue is known as "lacing".) Also, the need for a circuit board embedded in the glass and an outer electrode presented aesthetic design challenges.

SURFACE TAGS

As noted previously, Microsoft Surface works by shining infrared (IR) light from underneath the table, up through a diffuser, and watching for reflections via a series of IR-sensitive cameras in the table base. The diffuser plays a critical role in distinguishing a real touch event from an almost touch event. Without the diffuser, these two events would look highly similar. But with the diffuser, a finger that is on the Surface will give a sharply defined reflection, while one that is further away will not.

When a tag is placed on the Surface, the diffuser degrades the view of the tags. A good rule of thumb is that to see a reflective pattern well through a diffuser, if must be closer to the diffuser than the smallest feature size we wish to resolve. Further limitations are set by the resolution of the cameras and the quality of the lenses.

DYNAMIC TAGGING

Dynamic tags are tags that change their pattern over time. A simple example might be the push button shown in Figure 1. When the button is depressed, the contact area increases. One can think of the button as a transducer that transforms a physical variable into an optical one. Alternatively, one can consider it as a sensor with an optical output.

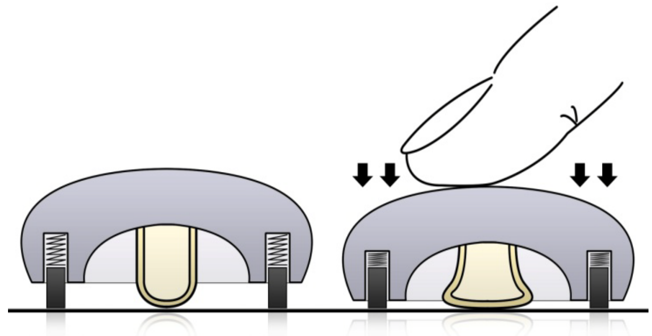

Figure 1. A simple pressure sensitive button increases contact area with increasing downward force.

An alternative way of building the example button would be to use an electric force sensor to control an IR LED that would communicate the dynamic variable (pressure) to the Surface just like an IR TV remote changes channels. This sort of active tagging is less desirable than the passive system described above for several reasons. It is more complex, it is more expensive, and it requires an independent power source. An active system of this sort would be most appropriate for passing data from an object with embedded electronics – where the additional cost would be minimal. In that case, it is not so much a tagging system as a more general data communication system.

It is worth noting that one obvious method of implementing an active tag, using an inexpensive LCD display, is problematic. Most LCD displays do not significantly modulate IR light [10].

Surface tags use a digital encoding scheme. It is a system of dots that are either present, or not, in their given locations. However, when measuring physical variables, we often find it convenient to use a more analog scheme, such as in the button which encoded a dynamic variable (downward force) as the area of reflection.

TRANSDUCERS

Dynamic tags can be thought of as transducers that convert physical variables into optical changes that are observable via Surface's IR system. Mechanisms that can accomplish this generally fall into two broad categories – those that convert the variable into a physical movement, and those that are based on materials which change reflectance in response to the variable.

In the era before electronics, most measuring instruments had a visible display to present the result of the measurement. Consider such devices as weight scales, compasses, and thermometers. These instruments converted their respective quantities to be measured into physical motion that could be visually observed. These mechanisms can be exploited to create simple dynamic tags for Surface that, for example, sense weight, magnetic field and temperature. Figure 2 shows a bimetallic coil such as is used in mechanical thermostats and thermometers that can be used as a dynamic tag to report temperature.

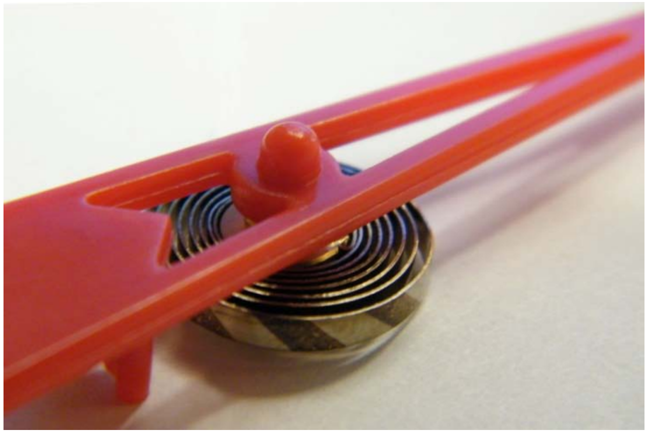

Figure 2 Bimetallic strips are often used in thermostats and thermometers. Here, we use one to create a dynamic tag that indicates temperature.

In chemistry and biology, there is a long history of measurement through reactions that change color. The best known of these chemochromic systems is litmus paper, which changes color based on pH level.

There is a wide range of materials which change reflectance based upon physical parameters. A brief taxonomy of such materials was given in [11] and includes:

Thermochromics - Temperature difference

Photochromics - Radiation (Light)

Mechanochromics - Deformation

Chemochromics - Chemical concentration

Electrochromics - Electric potential difference

These properties could be exploited to create different types of sensors which are Surface-readable.

While mechanical and smart material devices provide a rich source of ideas for how to create dynamic tags, there are other mechanisms that are possible. In the next section, we consider the problem of creating level-sensing glassware for Surface, and demonstrate an alternative approach.

LEVEL-SENSING GLASSWARE

Microsoft Surface has found application as an interactive table in a bar or lounge setting [4]. In this circumstance, Surface is used as an explicit interface – allowing guests to order drinks, play games, send messages, and provide entertainment. However, there is also an opportunity to improve the system by providing an implicit interface – one that detects the appropriate time to offer a refill.

Beverage sales are the primary source of revenue in a bar or lounge. A key component of that revenue stream is refill sales. It is common knowledge in the business that there is an optimal time to offer a refill. That is the time when the customer is most likely to accept an offer of another beverage. If the offer is made prematurely, when the glass is still largely full, they may feel unduly pressured. When the current drink is finished, the customer may get into the mindset that they are done drinking. So most establishments train their staff to offer a refill slightly before a drink is finished. Not only does this maximize the immediate sales, but it also creates the impression of good service, increasing the likelihood of repeat visits. Appropriately timed service also helps speed table turns, allowing more customers to be served at busy times. Such factors can have a large impact on the financial success of a business. Thus, a system that can alert servers when to offer a refill would be highly desirable. In the case of Surface, the system itself can offer the refill, assuring optimal timing.

One could imagine any number of ways of creating a dynamic tag that responds to fluid level. For example, we could measure the weight of a glass. However, in many cases, drinks come with ice, spoons, fruit, or other things that many remain in the glass even when the customer is done drinking. This limits the reliability of a weight-based system.

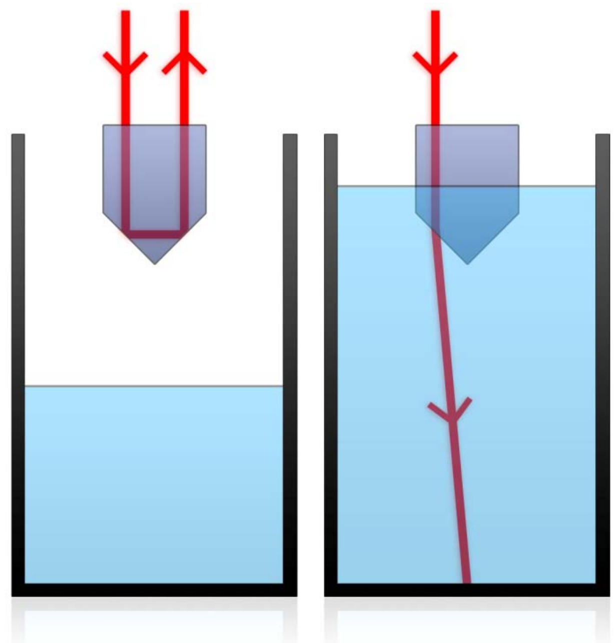

Figure 3. Gems Sensors optical liquid level sensors reflect light when the tip is in air, but do not when submerged.

The optical liquid level sensors sold by Gems Sensors and Controls [12] suggest an alternative solution. The basic design is shown in Figure 3. Light is guided to a pointed tip that acts like a reflecting prism. When the tip is in air, light travels down and hits the point at a sharp angle. Given the large difference in refractive index between air and the tip material, the light is completely reflected via total internal reflection. It then travels across the tip to the other side, where it is reflected back up. When the tip is immersed, the indices of refraction are closer, so much of the light escapes into the fluid rather than being reflected.

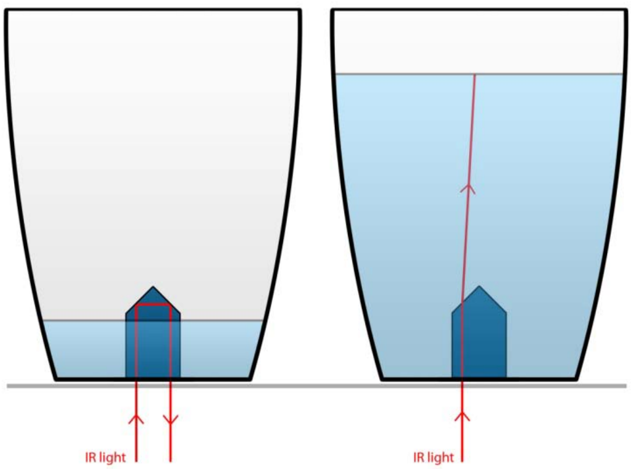

Figure 4. A SurfaceWare glass uses a prism-like structure to reflect light when it is not submerged.

A SurfaceWare Glass is shown schematically in Figure 4. A reflecting point is designed into the base of the glass. When it is placed on a Surface, IR light is directed up towards the point. The index of refraction of air is 1, for water it is about 1.3, and for glass or clear plastic it is typically around 1.5. The tip is angled at 45 degrees. The critical angle, at which total internal reflection occurs, is about 40 degrees for the tip/air interface. This is why all of the light is reflected when the tip is not immersed. For the tip/water interface, the critical angle is about 60 degrees. About 98% of the light escapes into the fluid on the first bounce. Of that light which is reflected, it bounces to the other side of the tip, where ~98% of the remaining light escapes into the fluid. Thus, the reflection after two bounces is almost nonexistent.

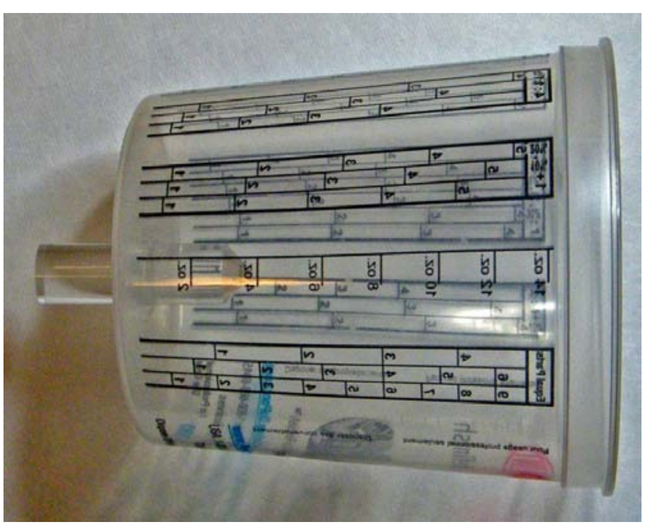

Figure 5. Original test cup uses a 45 degree pointed plastic rod.

We have created a number of different SurfaceWare prototype glass to validate the concept. Figure 5 shows our original test cup – a plastic cup with a pointed (45 degree tip) plastic rod inserted in the bottom. Figure 6 shows what happens when we shine a laser pointer up at the tip with and without fluid. As expected, the light reflects when the tip is in air, but passes through the fluid when the tip is submerged. Figure 7 shows a similar test, done with an ordinary flashlight, looking up at the base of the glass. The change in reflectance is very apparent. Finally, we placed the test cup on a Surface, and looked at the camera image as fluid was added to the cup. We were easily able to detect the change in reflectance.

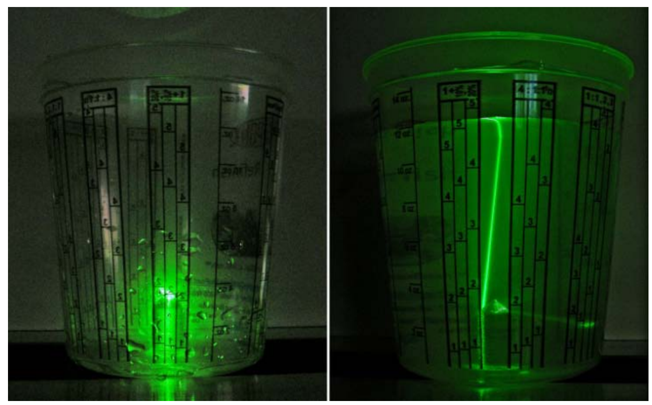

Figure 6. The test cup is shown with a laser pointer shining up through the plastic rod. In the left picture, the cup is empty, so the tip reflects. In the right picture, the tip is submerged, and the beam escapes up through the fluid.

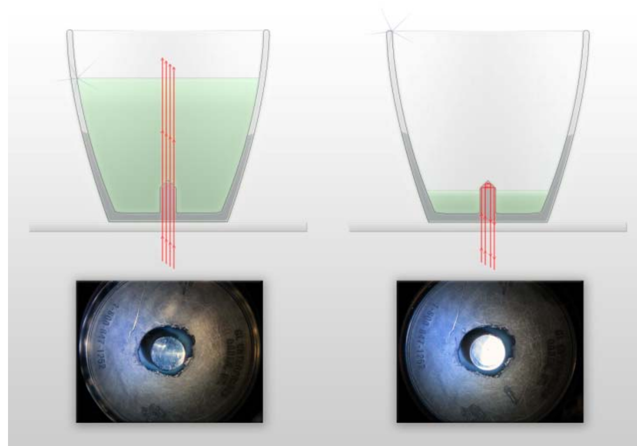

Figure 7. The test cup is illuminated from underneath with a flashlight. It is easy to distinguish the fluid level by the reflection.

In a busy setting, it can be helpful to know a bit before the optimal time to offer a refill so that table visits can be appropriately scheduled. Figure 8 shows a glass design with multiple reflectors at different levels. Note the use of a standard tag to indicate the presence and orientation of the glass. This lets Surface know where to look for the reflectors.

Figure 8. This SurfaceWare glass has three reflectors to allow a more detailed measure of drink progress.

The previous designs presented essentially digital information – i.e. a reflector was either reflecting or not. In fact, we observed that the amount of reflection varied as the fluid level varied between the bottom of the tip and the top. This suggested building an analog version of the glass with a single large reflector shown in Figure 9. This allows us to measure as the drink level progresses from the tip down.

Figure 9. A SurfaceWare glass with a single large reflector is shown. This allows for an analog measurement of fluid level once the drink level has progressed down to the tip.

CONCLUSIONS
In this work, we have demonstrated techniques for creating dynamic tags for use with Microsoft Surface. For the case of drink level sensing, a small modification to ordinary glassware adds new implicit interaction capabilities.

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