Using ForceForm, a Dynamically Deformable Interactive Surface, for Palpation Simulation in Medical Scenarios

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ABSTRACT
We present the initial exploration of using ForceForm, a dynamically deformable interactive surface, for an application in the medical domain. ForceForm provides direct dynamic interaction which is soft and malleable. We are interested in pursuing its use as a training tool in medical scenarios which involve the direct interaction with human skin. As an example of this, we have developed a palpation training application. Previous work in this area uses haptic devices which do not have the soft and direct interaction exhibited by ForceForm. This workshop paper details our palpation application and a discussion of the findings of an expert user consultation involving a doctor and a massage therapist.

Categories and Subject Descriptors
H.5.2 [Information Interfaces and Presentation]: User Interfaces - Interaction Styles

General Terms
Design, Human Factors.

Keywords
Interactive Surface, Tangible Interface.

1. INTRODUCTION
ForceForm [12] differs from traditional touch surfaces because it can be physically deformed by the user’s touch. It is well suited to medical training applications which involve direct interaction with human skin and the underlying tissue such as palpation. This is because localised areas of the simulated skin can be transformed from the soft and squishy initial state to be one of several levels of firmness.

Unlike related implementations, ForceForm allows direct interaction using any number of digits with a soft, skin-like surface. This soft and direct interaction is designed to be advantageous in scenarios such as palpation simulation. This paper outlines our initial exploration of these ideas within the medical domain.

Our previous work with ForceForm has been aimed at using it as a tangible interactive touch surface for everyday computing tasks. One of the advantages of this system is that it can be used for multiple purposes, allowing the user

![Figure 1: A doctor palpating the abdomen of a child.](http://commons.wikimedia.org/wiki/File:Child_examined_by_doctor.jpg)
to interact with tangible medical training applications and also perform traditional touch surface tasks in a tangible manner.

2. PALPATION

Palpation, in medical terms, refers to the use of touch and pressure to examine the size, shape, firmness and location of an object, such as an internal organ or growth, that is beneath the skin and not directly visible. The purpose of palpation is to assess the patient’s tissue and determine the location of features beneath the skin. It is undertaken by various health practitioners including general practitioners, chiropractors, physical therapists and massage therapists.

3. RELATED WORK

Pin arrays have previously been used to produce deformable surfaces. Feeler [5] consists of an array of linear actuators that are used to raise and lower rods which deform a white nylon cloth surface and the authors list palpation simulation as a usage scenario. Relief [8] is a similarly structured system, which consists of aluminium pins that are each actuated using a potentiometer. With the Obake [4] system, the user’s hand movements are tracked using a depth sensing camera. This allows the user to pull the surface up and have linear actuators adjust rods beneath the surface to retain the surface shape that the user formed by pulling up the surface. Shape memory alloy (SMA) wires have also been used to actuate pin arrays [10]. SMAs, however, have a slow reaction time in comparison to ForceForm. Pin array systems give a different interaction experience when compared to ForceForm. ForceForm feels soft to touch, however, with a system that uses pin arrays, the user is pushing down on a rigid rod which is less skin-like. Furthermore, palpation may require the user to make some movements upon the surface from an angle, rather than directly downwards, and it is unclear whether this can be achieved when interacting with pin arrays.

Touch surface overlays have been developed to add tangibility to touch surfaces. Harrison et al. [9] produced a soft overlay which consists of inflatable buttons. However, the buttons cannot be easily altered once the overlay has been made, and each button requires a pneumatic pump to be able to operate independently.

MudPad [6] consists of a pouch of opaque magnetic fluid that is used as a touch surface in conjunction with a projected display. The fluid is able to be stiffened using an underlying grid of electromagnets. The resulting change in viscosity is used to provide haptic feedback to a user touching the surface. MudPad requires increased magnetic strength to actuate the fluid, and this constraint may not allow the user interface designer the flexibility of being able to scale the system down.

The Phantom device [9] has been used in medical scenarios. Although it offers high fidelity feedback, it is also tethered, the interaction is usually not direct (rather a stylus is used) and there is commonly a mismatch between the location of the interaction and the display. Some previous work has aligned the interaction location and the display that the user sees, as in [2], but this is still using a stylus and therefore not suitable for palpation scenarios in which the skin is felt with the hands. Recently, the Phantom has been adjusted for a palpation scenario by having the user press a pad with their fingers rather than use a stylus [13]. However, a maximum of two fingers can be used on the pad, and the display cannot be aligned with where the user is interacting. The Phantom is also a specialised piece of equipment, but ForceForm is able to act as a traditional touch surface, allowing for many other everyday tasks to be undertaken with the same equipment. Other previous work has used the Phantom to apply forces to actuate the pins in a pin array [7]. HIRO [1] is another haptic interface that has been used to simulate breast palpation, however the point of contact with the interface and the visual representation of the virtual model being manipulated are not aligned.

4. FORCEFORM

As illustrated in Figure 2, ForceForm consists of a latex surface (a) that has been augmented with a grid of neodymium permanent magnets, which are arranged in phase. We use an underlying grid of 16 computer controlled electromagnets (c), similar to that of the Actuated Workbench [11], to attract and repel the neodymium magnets, deforming the surface at localised points. There is one permanent surface magnet per electromagnet in our prototype system. A 2mm Perspex sheet (b) lies between the deformable surface and the electromagnets, to prevent the surface magnets from attaching to the ferrous cores of the electromagnets. Finger
position is tracked using a Cyclotouch$^2$ T-series touch overlay. A steel baseplate (d) improves the strength of the electromagnets. Since we track the user’s finger position, we are able to detect when the user is touching a lump, for example. The system has a 6ms response time, so the surface is able to be deformed in a manner that appears dynamic. More of the technical information about the ForceForm prototype, including measurable performance parameters, can be found in Tsimeris et al. 12.

5. INTERACTION CHARACTERISTICS
In our initial prototype, the surface of ForceForm was able to move up and down at localised points forming either dome shapes or indents. For this application domain, we have increased the space between the latex surface and the underlying perspex sheet from 10mm to 15mm. The result is that when an electromagnet repels a permanent magnet on the surface, the localised point feels firmer to the user’s touch in comparison with the rest of the surface. This concept is illustrated in Figure 2b. Minimal protrusion above the surface is present. Different strengths of repulsion from the electromagnet result in different levels of firmness at the user’s touch. When the user pushes down on the surface, they may eventually touch the perspex sheet, as shown in Figure 3. This is comparable to how skin and tissue are soft to the touch until bone is reached.

Thus, when no electromagnets are switched on the surface feels soft to touch. When the electromagnets are repelling, the surface feels firmer. When the electromagnets are attracting the surface, indents can also be formed, however, we are yet to use this indention functionality for the purpose of a medical application.

As mentioned, ForceForm is a prototype system, and there are hardware parameters that can be altered. We are currently experimenting with different surface materials such as neoprene, which may feel more like skin, and different surface construction methods to improve the prototype latex surface. One of the advantages of this system is that it could be used for multiple purposes, allowing the user to interact with tangible medical applications but also perform traditional touch surface tasks in a tangible manner. When used with an opaque surface, ForceForm can be projected upon, which may aid interaction in both medical and desktop scenarios.

6. PALPATION USING FORCEFORM
We have implemented a palpation application using ForceForm. The user is able to run their fingers along the latex surface which simulates skin. When an electromagnet is set to repel a permanent magnet on the surface, a greater resistance is felt when pushing down at that location, as shown in Figure 2b. This means that the localised point feels firmer to the user’s touch in comparison with the rest of the surface, which simulates the lump. The electromagnets are each able to repel at different strengths, resulting in change in the firmness of the lump.

As we have tracked the location of the user’s touch, we know when the user has located and is touching the firm point. When this occurs, we cease to energise that electromagnet and instead energise an adjacent electromagnet. This allows us to simulate the lump moving from side to side under the skin, as a result of the user pressing where the lump is located. The validity of this scenario was confirmed by our discussion with a doctor. There are scenarios where a lump such as those we are simulating can be felt, and the lump will move as the result of pressure being applied. One possible example of such movement is in palpation of lumps in the breast.

7. EXPERT FEEDBACK
We invited a medical doctor (MBBS), who works both in general practice and teaches in the medical school, and a massage therapist who has worked in both general massage and remedial massage in the sports domain to experience the ForceForm prototype. These expert users interacted with our palpation application in ForceForm and we received feedback on both the specific palpation application, particularly from the doctor, and other possible medical training uses of the system.

Discussion with the doctor. We discussed the possible use of the system for training of the health workforce, especially those who are remotely located. Current training practices in this area usually consist of the trainee feeling the lump of a real patient, which is a very accurate method. However, according to the doctor there may be scenarios where there is a shortage of available people with the desired medical conditions to act as subjects for medical training. An example of this may be in Indigenous communities in remote Australia. In these cases, a substitute such as our application could be an option. Furthermore, if it were to have a place in medical training, it would aid in early training rather than later medical training, where the texture and finer details of lumps would need to be assessed. It may be more efficient to use our system for initial training and use real patients subsequently. It is apparent that, in practice, detecting any lump at all is the first step, and once a lump is found then it is able to be medically imaged to ascertain its likely nature.

It was also suggested by the doctor that ForceForm could be used for medical student practical examinations. The system allows for a predetermined setting to be recalled so that many students can be tested with the same exam. Our
current application simulates the kind of lumps that can be found in the breast region. The simulation of firmness in the abdominal region could also be possible and is desirable according to the doctor, as this would allow detection of internal organ problems such as an enlarged liver.

After discussion with the doctor, we believe ForceForm can aid in training for the discovery and identification of lumps underneath the skin using palpation. Since a lump is usually medically imaged once found, the problem is to determine whether there is a lump, and where it is. We are confident ForceForm can aid with training for these tasks, and can be used alongside other techniques in a full training package.

Discussion with the massage therapist. One of the tasks of a massage therapist is to identify tight muscles and massage them in order to make them looser. Tight muscles feel firm and in this state it is difficult to differentiate between the different muscles. After the tight muscles have been massaged, they feel softer and it is possible to identify each separate muscle. The massage therapist interacted with our system and commented that it could be used for the training of this technique as it can simulate this transition from firm to soft as the firmness can be dynamically altered.

The massage therapist had completed part of her training remotely. As part of this process, she received instructional videos demonstrating massage techniques. She was then to replicate techniques from the video at a later date at an exam. She said that, due to the hands-on nature of the task, it was difficult to learn from watching a video and it would have been better to receive this training in a hands-on manner. The tangible nature of our system makes it suitable for this scenario.

8. CONCLUSION AND FUTURE WORK

We have presented the initial exploration of using ForceForm, a dynamically deformable interactive surface, as a training tool in medical scenarios which involve direct interaction with human skin, such as palpation. We are interested in using ForceForm for these tasks as it enables direct, dynamic interaction with a soft surface that is similar to human skin. We have described our palpation application and we have presented feedback from a doctor who also has experience in medical teaching. This feedback has revealed that the texture is also important in the diagnosis of lumps. It is evident that there may be uses for this system, particularly for the training of those in remote locations and for early lump detection, before medical imaging is performed. We also received feedback from a massage therapist who highlighted the need for a training system to support tangible and dynamic interaction.

ForceForm is a prototype system and there are a number of hardware components that can be altered in order to alter various performance metrics to suit the application. These include the size of the electromagnets, the power used, the size and shape of the permanent magnets, the material used for the deformable surface, whether it is slippery or has grip, and the tension of the surface. ForceForm can be scaled to achieve a finer resolution than our current system achieves and the number of electromagnets can be increased to suit the size of surface required.

We hope to expand this work to address how ForceForm could be used for other medical scenarios, for example, the simulation of internal organ problems such as an enlarged liver. It may also be useful to speak with doctors who have experience in health care in remote settings, and those in particular fields that have a high level of contact with human skin, such as dentistry and plastic surgery.

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10. REFERENCES