Pilot Study: Low Cost GelSight Sensor

Alexander C. Abad[1], David Reid[1], Anuradha Ranasinghe[1]

***Abstract*— GelSight sensor and related technology have been studied a decade to the date. It was proven that it is worth to explore in many haptics and tactile sensing applications. Elastomer, reflective coating, lighting, and camera were the main challenges of making a GelSight sensor within a short period. In this workshop paper, we present our preliminary studies on how to make a GelSight sensor using low cost material. In this study, we used a clear silicone cosmetic sponge as the elastomeric slab and that skipped the degassing process and hours of curing time in making it. Moreover, we used Psycho Paint® for the reflective coating, Light Emitting Diodes (LEDs) for the lighting, and Logitech C270 webcam for our experimental setup. Furthermore, in this study Ultraviolet (UV) ink and UV LEDs have been tested as a marker for the reflective coating and lighting respectively. UV ink markers are invisible using ordinary LED but can be made visible using UV lighting. Comparable results have been found to show the effectiveness of our setup.**

I. Introduction

Clear elastomer covered with reflective skin is one of the basic component of GelSight sensor [1]. Current GelSight elastomers are created in the lab. Clear elastomer can be made using thermoplastic elastomers (TPEs) and silicones [1], [2]. According to Yuan et. al. [2], TPEs typically requires an oven to melt in a mold in an hour to form the desired shape while clear silicone elastomer can be made by two separate liquid parts that react and solidify to form a gel when mixed together. The curing time is about six or seven hours [2]. One major problem in preparing TPE and silicone to create clear elastomer for GelSight is the formation of air bubbles within the gel. Vacuum pump is necessary to eliminate the air bubbles and the process is know as degassing [2]–[4]. According to Li et al. [5], they had challenges in the production of gels made in their lab because the quality or properties of each may vary and hard to be controlled well for consistency. The authors in [5] suggested using 3D printed transparent gels applications in the future.

This workshop paper discusses how to create a low cost GelSight sensor using commercially available clear silicone cosmetic sponges shown in Figure 1. This paper is structured as follows: review of related literature is discussed in section II, available materials and low cost GelSight construction are discussed in section III, evaluation of constructed GelSight with silicone sponge is discussed in section IV followed by conclusion and recommendation in section V.

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[1] Alex, David, and Anuradha are with the Department of Mathematics and Computer Science Faculty of Science Liverpool Hope University Hope Park — Liverpool L16 9JD. UK. abada@hope.ac.uk; reidd@hope.ac.uk;dissana@hope.ac.uk

(a) Transparent silicone sponge. (b) Silicone sponge with pink cushion.

Fig. 1: Commercially available silicone cosmetic sponge.

II. Related Literature

GelSight sensor was introduced by John and Adelson a decade ago [1]. It is a high-resolution vision-based tactile sensor. It is composed of a clear or transparent elastomeric slab with a reflective coating on one side that will act as the sensing surface. The slab is supported by a clear glass or transparent acrylic plate. Illumination can be provided by Light Emitting Diodes (LEDs) mounted on different positions around the transparent supporting plate. A camera is placed a the back of the supporting plate to capture deformation images under illumination from different directions [6].

GelSight sensor evolved from bulky structure presented in [1] to a portable configuration presented in [6]–[8]. A fingertip GelSight sensor was presented in [9] and was later improved in [10]. The latest iteration on GelSight sensor physical structure was introduced in [11] known as the GelSlim.

GelSight sensor was used in measurement of surface texture [1] and microgeometry [7], lump detection [6], measurement of shear and slip [10], [11], [13] using the markers in the elastomer introduced by Yuan et al. in [2], [12]. Recently, GelSight sensor have been used in cloth or textile characterization [14], [15].

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(a) Shore A reading for transparent silicone sponge. (b) Shore A reading for silicone with pink cushion.

Fig. 2: Shore A measurements of silicone sponges.

III. A LOW COST GELSIGHT SENSOR CONSTRUCTION

A. Elastomer

Commercially available silicone sponge as shown in Figure 1 was used as an elastomeric slab. As shown in Figure 2, Shore A values for silicone sponge (a) and silicone sponge (b) are 7 and 2.5 respectively. Silicone sponge shown in Figure 1a is clear and transparent while Figure 1b has a pink cushion on the other side that can be easily removed by cutting the edges around of the silicone sponge as shown in Figure 3.

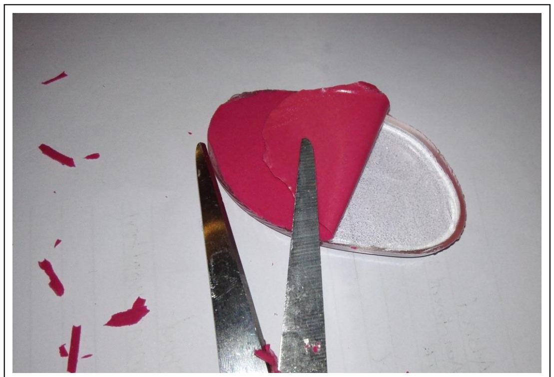
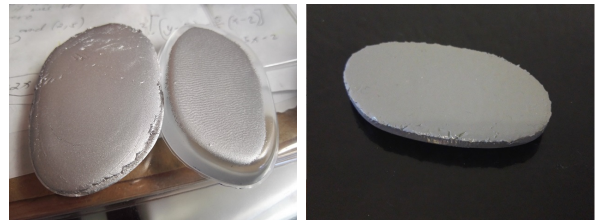


Fig. 3: Removing the pink cushion of silicone sponge.

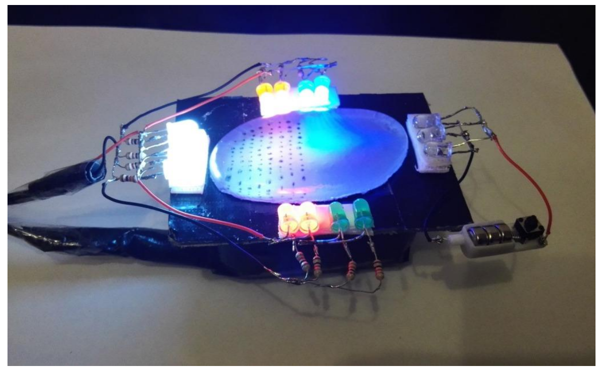
B. Reflective Coating

Silicone in Figure 1a can be painted on either side as shown in Figure 4a. Without removing the thin plastic covering of the silicone sponge, silver metallic spray paint can be used as a reflective coating. Higher resolution or clarity of image can be achieved by removing the thin plastic covering of silicone sponge of Figure 1a. However, spray paint do not stick properly on silicone and will crack eventually when pressed. The reflective coating that can be used in silicone has been discussed in [2], [16]. We used Psycho Paint® [17] from Smooth-On Inc. To create a gray color similar to aluminum, we mixed white and black pigments of Silc Pig™ [18]. Then, we dilute the Psycho Paint® with pigment

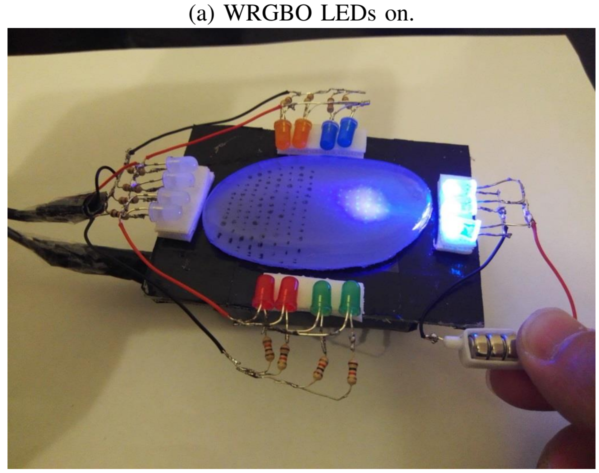


(a) After coating: the silicone sponge in Fig. 1(a). (b) After coating: the silicone sponge in Fig. 1(b).

Fig. 4: After coating.



(a) WRGBO LEDs on.



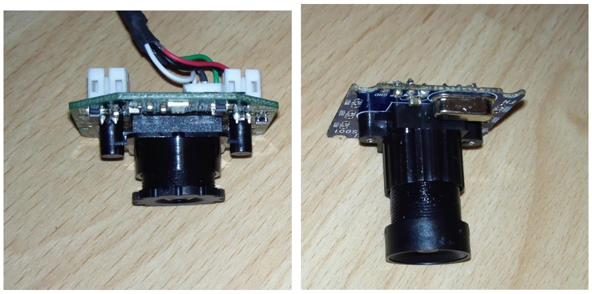
(b) UV lights on.

Fig. 5: LED Lighting.

using Novocs™ Matte [19] and used an airbrush to spray the mixture on the silicone sponge as shown in 4b.

C. Lighting

Uniform and controlled background lighting condition is necessary to illuminate the elastomeric slab. LEDs are used in this study to provide controlled lighting. Different LEDs with different colors mounted at different positions around the slab are required to detect the surface normal in R^3 space [2]. Yuan et al. [2] discussed that using photometry stereo technique, impressed image on the reflective coat-



(a) Low profile webcam lens. (b) High profile webcam lens.

Fig. 6: Webcam lenses.

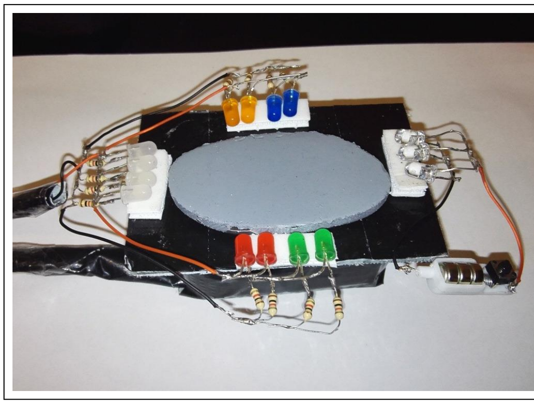


Fig. 7: Experimental setup.

ing of elastomeric slab can be reconstructed in 3D using differentiated illumination direction. According to [2], there are two ways to get differentiated illumination direction: 1) switching different LEDs positioned at different locations and take separate pictures on the same scene, and 2) using multi-color LEDs simultaneously and take a single picture; reflection of different color LEDs can be known by taking different channels of the color image. In this study, aside from multi-color LEDs, UV LEDs were also used. Shown in Figure 5a, multi-color LEDs (white, red, green, blue, and orange) are lit to shine on the inverted silicone sponge to show the permanent markings on the reflective layer. On the other hand, shown in Figure 5b, UV LEDs are switched on to show the presence of UV markings in the reflective coating of the silicone sponge which are not visible in Figure 5a.

D. Camera

Webcam lenses shown in Figure 6 have an adjustable focus by rotating the lens. On the other hand, they have different height. We used Logitech C270 webcam [20] in this study. Although it has been stated in [20] specifications that the webcam has fixed focus, with the help of [21] we were able to adjust the focus manually and got a clear image even at 1.5-inch distance from the camera.

E. Experimental Setup

Experimental setup is shown in Figure 7. The supporting structure for silicone sponge is a clear glass with a dimension of 2.5 inches x 3.5 inches. Multi-color LEDs are mounted on top of the glass to create a uniform lighting as the light diffuses on the body of silicone sponge. All LEDs, with a limiting resistor in one leg, are connected in parallel powered by 5V USB supply. Aside from multi-color LEDs, UV LEDs are also mounted in the experimental setup to show UV markings when switched on. In this study, we used UV pen marking with built-in UV Light [22].

IV. Evaluation of Results

With enough background light and clear glass support for the silicone sponge, one can see the embossed or protruding image in a coin, a fingerprint, and bank note marking pressed

(a) One peso coin marking. (b) Fingerprint marking.

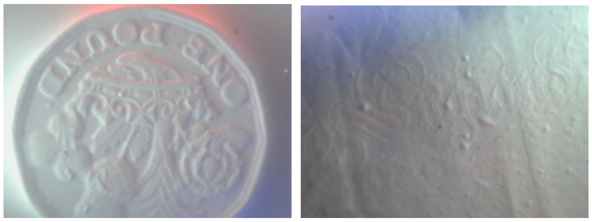
(c) Banknote marking. (d) USB marking.

Fig. 8: Results from visual inspection.

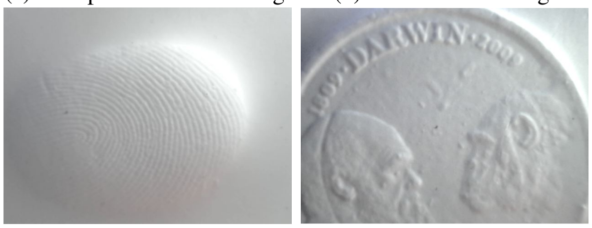
on the reflective surface of silicone sponge as shown in Figures 8a, 8b, 8c. Sunken or depressed image of a USB marking on a USB plug can be also be seen as shown in Figure 8d respectively.

To ensure uniform lighting, the experimental setup shown in Figure 7 was used to get the coin markings shown in Figures 9a and 9d, the bank note marking shown in Figure 9b and the fingerprint marking shown in Figure 9c.

We also tried to experiment on using ultraviolet ink as a new form of marker for our GelSight. To the best of our knowledge, this is the first time to report the use of a UV ink for GelSight marking. UV ink markings are invisible to ordinary LEDs. We used UV LEDs to see the UV markings. When we want to study shear and slip, we need markers to track the deformation in the reflective coating. Instead of the black and permanent markers used by Yuan et al. [2], UV ink was used in this study. UV markers can be seen using UV light as shown in Figure 10a. When we want to study texture and microgeometry, we do not need the markers. We

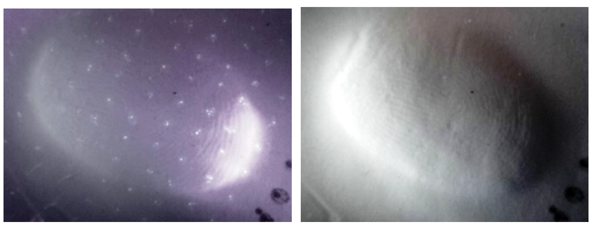


(a) One pound coin marking. (b) Banknote marking.



(c) Fingerprint. (d) Darwin.

Fig. 9: Results from experimental setup.



(a) UV marking on. (b) UV marking off.

Fig. 10: Results for UV marking on and off.

turn off UV light and the UV markers become invisible. The result is like the typical image result of GelSight as shown in Figure 10b.

V. Conclusion and Recommendation

In this study, we were able to show that we can make a low cost GelSight sensor in a short period of time for testing. We used silicone cosmetic sponge as an elastomeric slab to create a GetSight sensor to skip the degassing process and the hours of curing time n creating a clear silicone slab. Moreover, we proposed UV markings to study shear and slip. Switching the UV light, UV markers would become visible. Furthermore, it can be turned off when we study texture and geometry. The preliminary study results show that this can be used in haptic exploration applications in the future. We would explore more on the main challenges such as elastomeric slab, lighting, reflective coating, and camera in-house in the future to enhance the resolution of the images.

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