Idea

Use a phone's camera to sense interaction with a 3D-printed object. Previous work uses conductive filament to "pass through" touches from the object to the screen, but then the screen gets covered. Can we somehow use the camera to keep the screen unobscured but support rich input? Maybe a mirror mounted on the back of the phone could let the camera see printed objects attached to the back or edges.

Possible applications

Games are really popular on phones but can be hard to play with just the touchscreen, and controller cases don't necessarily fit all games. This project could enable a custom-made game controller where the controls are printed to match the game. So a racing game might have a steering wheel shape with paddles for shifting, and a shooting game could have a gun trigger.

We can add emojis to text messages to express emotion, but we have to find the right one. This project could let us squeeze a soft attachment in different ways to express emotions while we write a message, and automatically insert an emoji that matches the emotion.

Accessibility features for people with visual impairments aren't great on phones. It's hard to find the right controls. This project could make phones physical again by adding a set of buttons with easy-to-distinguish shapes for launching apps, setting alarms, or doing other common tasks that might be hard without being able to see the screen.

Related papers

Acoustruments

This paper adds different kinds of widgets to a mobile phone, using sound to detect interaction. The basic approach is to emit a broad-spectrum sound from the bottom speaker of the phone, route the sound through a pipe to the bottom microphone, and place different structures in the pipe that change the sound in different ways depending on the user interaction. The pipes are fairly complicated and have to be printed on a high-resolution printer, and the system requires machine learning to recognize user interaction. The only necessary resource other than the printer is a mobile phone. The sound recognition required some knowledge of audio processing and machine learning, while creating the widgets needed basic CAD skills and a lot of experimentation time. The authors demonstrated the main concept of using sound to detect interaction, but did not create a design tool or any applications beyond some very basic demos.

Laput, G., Brockmeyer, E., Hudson, S. E., & Harrison, C. (2015). Acoustruments. Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems. https://doi.org/10.1145/2702123.2702414

Sauron

This paper is quite similar to the project idea. It adds interactivity to 3D-printed objects using a camera and (optionally) mirrors. However, the system is complex, because it requires that the user design the object beforehand on a computer, which has to calculate how to modify the widgets in order to let the camera see all of them. Each widget has reflective or contrasting ink on it that lets the computer vision software track its movement. This project required understanding of computer vision and writing plugins for CAD software. The authors implemented a fairly complete system including a design tool and tracking software.

Savage, V., Chang, C., & Hartmann, B. (2013). Sauron. Proceedings of the 26th Annual ACM Symposium on User Interface Software and Technology. https://doi.org/10.1145/2501988.2501992

Clip-on gadgets

This paper uses capacitive sensing on touchscreens to add extra controls to mobile devices. The main idea is to transmit a user's touch through a physical object to the edge of the screen, and to modify the software to pick up the "fake" touches in a thin band at the edge. It's not entirely clear from the paper how their hardware implementation works, but to do it with 3D-printed objects would require a printer that can print in two materials. One drawback to the technique is that it can only detect a clipped-on widget when a user is touching it, which limits the interaction possibilities. The main skills here involved programming the mobile device, and understanding how capacitive touch sensing works. It doesn't look like a lot of "gadgets" were implemented, but the paper illustrates the basic concept well with a working demo gadget.

Yu, N.-H., Tsai, S.-S., Hsiao, I.-C., Tsai, D.-J., Lee, M.-H., Chen, M. Y., & Hung, Y.-P. (2011). Clip-on gadgets. Proceedings of the 24th Annual ACM Symposium on User Interface Software and Technology - UIST '11. https://doi.org/10.1145/2047196.2047243

Potential explorations

Note we're only providing one example here, but you need to do at least three!

Exploration 1

The core concept is detecting movement of rigid, 3D-printed widgets on the edges of a phone using a cone-shaped mirror to let the camera see all of the edges, and colored markers that move with the widgets. To explore this idea, I would need to buy or make a cone-shaped mirror and experiment with what it can see around the edges of a phone. I would also need to figure out how to make the movements of different widgets detectable and distinguishable from each other. Maybe 3D-printed gears could translate different movements of widgets into motion that's detectable?

This exploration will require basic optics knowledge to think about the mirror; computer vision to detect the widget movement; and 3D modeling to make the widgets. I'm not sure where we can find the mirror, but the widgets can probably easily be printed in the lab. I took a computer vision class once, and I'm quite experienced with 3D modeling.

We can prove the basic concept with some very simple widgets, maybe even made out of cardboard instead of 3D printed, and the final project can just show that the widget movement can be detected. We can skip a design tool and probably don't need any fancy apps.

Exploration will have to start with finding out how to make or buy a cone-shaped mirror. They look quite expensive to buy, but I think we can get some reflective film from the hardware store and glue it to a 3D-printed cone. Then we would need to test different kinds of ways we might detect widget motion with the camera. Maybe some colored pieces of plastic attached to each widget could work. Next we'll need to figure out how to model the widgets so that their motion can be seen by the camera. And finally we'll have to have some computer vision software that can actually track the motion.

Success for this idea will look like being able to track the motion of three physical 3D-printed widgets, such as a button, a dial, and a slider.