Project Proposal: RainCheck
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Project Title: RainCheck

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Project Description:

RainCheck is an initiative to develop smartphones whose touchscreens function well even in the presence of water on the touchscreens: when it is raining, or our fingers are wet. Most modern smartphones use a grid of capacitive sensors to detect touches on the screen. Capacitive means the sensors have the ability to absorb, or store electrons. When you touch a capacitive touchscreen with your finger, you cause a change in the screen's electrical field – a change in the capacitance values of the region of the screen you touched. Fingers are capacitive, which is why touchscreens work so well with our fingers, but so too are water droplets. Thus, the major challenge of making the touchscreen robust to water droplets is the fact that water droplets change the capacitance of electrodes on the screen in a similar way to a user's fingers. The touchscreen gets confused between water droplets and our fingers, and irregularly registers "false touches" at different points on the screen due to the presence of water.

This project involves hacking into the Android kernel and modifying the existing touchscreen code. Isaac Zinda, a student who worked previously on the RainCheck project, implemented a procedure that records all touches (real and false) registered by the touchscreen. In addition to recording the (x, y) coordinates of the location of the touch point, the algorithm computes a "capacitance matrix" – a grid of the capacitance values of all the points on the touch screen. Using the capacitance matrix approach, we can find the entire region of points on the touch screen whose capacitance values have changed due to either a user touch or the presence of water. Developing and testing an algorithm which processes the data to distinguish between real, finger-based, and false, water-induced interaction, optimizing the algorithm in terms of running time/speed, and making the process run in real time are important goals of the project.

If the project is successful, we will have developed a novel method of developing smart phones that are easy to use in the rain and with wet hands. Just download our new custom Android kernel, and your phone will incorporate our new algorithms for distinguising between water droplets and your fingers. We will have moved from water-resistant touch screens that do not break down in the presence of water) to screens that actually enable wet finger tracking. This project is a crucial step in transitioning from simply protecting mobile devices *from* water, to actually *using* mobile devices *in* the presence of water. Taking this one step further, we can imagine setting the stage for the development of a new class of robust devices that are usable in a variety of unsatisfactory wet, soapy, dirty, or grimy environments & conditions.

My faculty mentor for my research project is Professor Mayank Goel, Assistant Professor in the Institute of Software Research and the Human Computer Interaction Institute. Mayank Goel previously worked on the RainCheck project in Professor Shwetak Patel's UbiComp Lab at the University of Washington. I will also be working in collaboration with Tony Tung, a PhD student, and Aishwarya Mandyam an undergraduate at the University of Washington.

Project Goals:

75%: The primary goal of the project is the development of Machine Learning models to differentiate between real and false touches on the touchscreen. The first step is to design and conduct an experiment collecting data on the way the touch screen reacts to different user interactions when the screen is wet in order to identify potential problem points. For example, we hope to quantitatively determine what specific gestures: (e.g.: swipe, tap, or pinch & zoom) are error-prone when performed on a wet touch screen or with wet fingers. From the data we collect, we hope to identify important features for the development of Machine Learning models to differentiate between real and false touches for *one or two* specific gestures. We will evaluate our models in a *controlled* setting (e.g.: control the amount of water on the screen and the particular user interactions for testing the models).

100%: We hope to extend the Machine Learning models developed in the 75% goal for distinguishing between real and false touches to *all* common touch screen gestures. In addition, we hope to enable our algorithm to run in *real-time* as the user uses a smart phone in the presence of water in order to distinguish real from false touches on the screen. We will evaluate our models in a more *naturalistic, variable* setting (e.g.: test the models outdoors in the rain, or in the shower).

125%: If we are able to develop a real-time ML algorithm that reliably distinguishes between real and false touches on the touch screen for common user interactions, another line of work we hope to pursue deals with *user touch typing* – a common activity with an *intensive* amount of interaction between user and screen. Touch typing is a smart phone interaction that is likely to be significantly degraded in the presence of water. We are looking at a combination of two different approaches to improve touch typing in the presence of water. The first approach is to reconstruct the "true" touch typing path from the "incorrect" path inferred by the phone (distorted due to the presence of water). The second approach is to reconstruct the real message the user intended to type from the incorrect message the phone thought the user typed using Natural Language Processing techniques. With a combination of these approaches, at both the "path" level and the "message" level, we hope to improve touch typing on smart phones in the presence of water. We will evaluate the quality of our algorithms in a *naturalistic, variable* setting.

Milestones:

1st Technical Milestone for 15-300: Build and download the Android kernel onto my machine and familiarize myself with the relevant functions of the kernel code. Make simple modifications to the code. Get Isaac Zinda's algorithm for retrieving the phone's capacitance values as users interact with the touchscreen running on my machine. In general, get up-to-speed with the current progress made by the team on the RainCheck project.

Bi-weekly Milestones for 15-400:

- *January 30th:* Finalize design & logistical details of the experiment to collect data on different user interactions for the Google Nexus 5 when the phone is wet.

- *February 13th:* The initial data collection phase of the project should be complete. At this point, we should have selected a set of specific gestures/user interactions that are significantly degraded in the presence of water that we wish to focus our research on. Start work on developing Machine Learning algorithms for distinguishing between finger-based, and water-induced interactions.
- *February 27th:* Continue work on developing Machine Learning algorithms. Start evaluating the results of the Machine Learning models for distinguishing between real, finger-based and false, water-induced touches in a controlled setting. Start addressing the problem of touch-typing in the presence of water. Work on the first approach: constructing the real touch-typing path from the incorrect path recorded by the phone.
- *March 20th:* Finish evaluating the results of the Machine Learning models in a controlled setting. Continue work on user touch-typing. Work on the second approach: construct the real message typed by the user from the incorrect message the phone recorded. Begin work on extending the algorithms for use in a more variable, natural setting, making modifications to the algorithms as necessary. Start work on enabling the algorithms to run in real-time.
- *April 3rd:* Finish work on enabling the algorithms to run in real-time. Evaluate the results of the new Machine Learning models developed for use in real-time. Continue work on user touch-typing. Begin work on the research poster and paper for the Meeting of the Minds project report.
- *April 17th:* Finish work on touch typing in the presence of water. Evaluate the results of the Machine Learning models developed for touch typing. Continue work on the research poster and paper for the Meeting of the Minds project report.
- *May 1st:* Finish the research poster as well as any papers written on the research.

Literature Search:
The main background materials are the RainCheck project website and Git repo containing details of previous work done on the project. We don't have papers that are directly addressing our research question, but Touché below focuses on a similar problem of enhancing touch sensing technology for a variety of different materials including liquids.

1. RainCheck website: contains instructions on building & downloading the Android kernel. The website also provides steps for making modifications to the kernel to retrieve the raw capacitance values of electrodes on the touch screen (URL: https://ubicomplab.github.io/RainCheck/)
2. RainCheck project Git repository: contains code for the new custom Android kernel developed by Isaac Zinda, as well as code on displaying a live view of the data coming from the kernel. (URL: https://github.com/isaaczinda/RainCheck)
3. Munehiko Sato, Ivan Poupyrev, and Chris Harrison. 2012. Touché: enhancing touch interaction on humans, screens, liquids, and everyday objects. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '12). ACM, New York, NY, USA, 483-492. DOI: http://dx.doi.org/10.1145/2207676.2207743

Resources Needed: I will need a Google Nexus 5 Phone and a Linux distribution (Debian/Ubuntu) on which to build and download the Android phone kernel and make modifications to it. These will be provided by Professor Mayank Goel.