UNIVERSITY OF
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Final Report
Track-a-Mole
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Introduction

Skin cancer is an affliction that affects millions of North Americans every year [1][2]. People are not always able to notice subtle changes in their skin, but these changes can have grave consequences if untreated. The 5-year survival rate for stage 3 and 4 skin cancer is 63.6% and 22.5% respectively [3]. Moreover, it is costly and inconvenient for a user to go to the doctor for every change they notice on their skin. For this reason, an app that can notice and record these subtle changes is ideal for earlier detection.

The goal of Track-a-Mole, our newly developed app, is to help users track their moles by allowing them to document any changes in their skin's condition. Additionally, the app is able to perform basic analysis, such as detecting size and symmetry, on these documented moles to further assist the user in maintaining their health. On top of that, the user will be able to see for themselves how the mole has changed over time, so they can seek medical attention if they wish to do so. To facilitate this, the app will allow users to give their doctor access to this information so that they can receive a proper diagnosis and further treatment.

Statement of Functionality

This application has different features that allow users to record and view their moles.

Recording a Mole

Users can take a picture of their mole using the camera on their device. Before taking a picture, they are asked if they are recording a new mole or tracking one that they have previously added. This allows them to keep track of how specific moles evolve over time. The user either enters a unique name for a new mole or chooses an existing mole name from the drop-down menu, as seen in Figure 1.

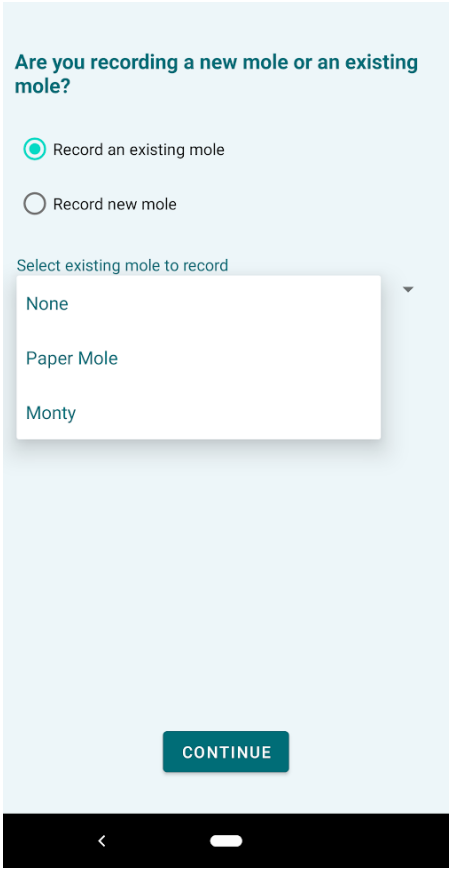


Figure 1

After the mole name is entered, the user is able to take a picture using the camera on their device. Either the front or back camera can be used, however, it is recommended to use the back camera to ensure correct capture of the mole (it also typically has higher resolution). Users are advised to take the picture from 5 cm away. This is to allow a close approximation of the real-world size of the mole through the image.

Analysis of the Mole

After taking a picture of the mole, image processing is performed in the background. This generates potential answers to some of the questions in the questionnaire (discussed later) and highlights the mole of interest for the user. In the foreground, the user would be taken to a questionnaire page (Figure 2). Here they would be able to see an image of the mole and have the opportunity to provide additional information that would be saved along with the image. They can choose to auto-populate some of these fields (like symmetry and size) based on the analysis performed at image capture (Figure 3). If they gave answers that showed cause for concern, the application would alert them to discuss their situation with a physician.

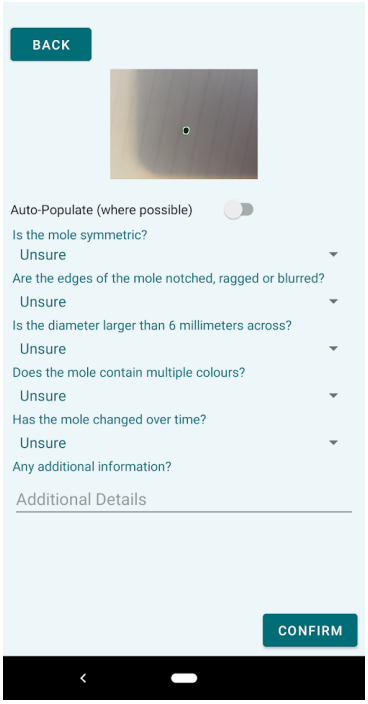


Figure 2

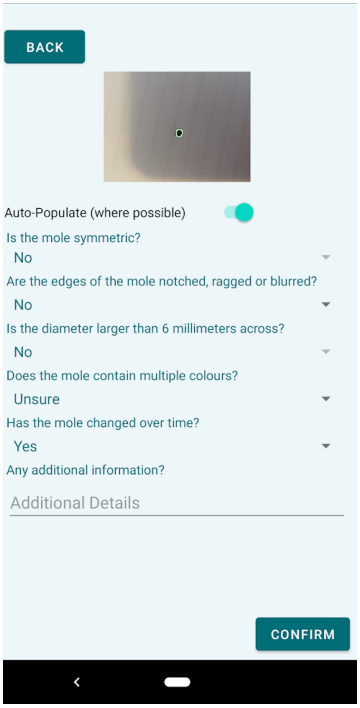
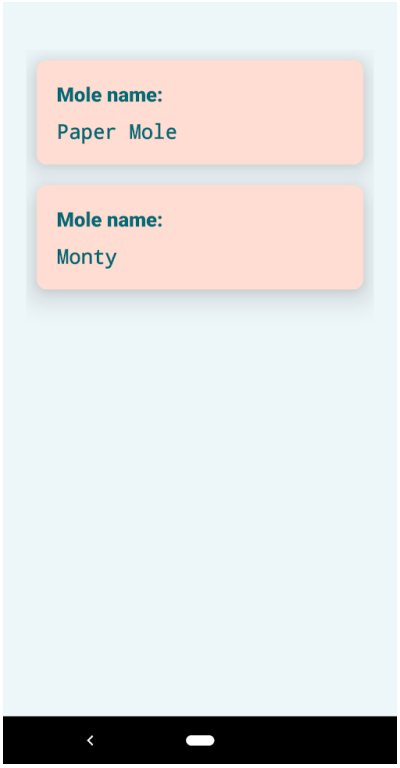
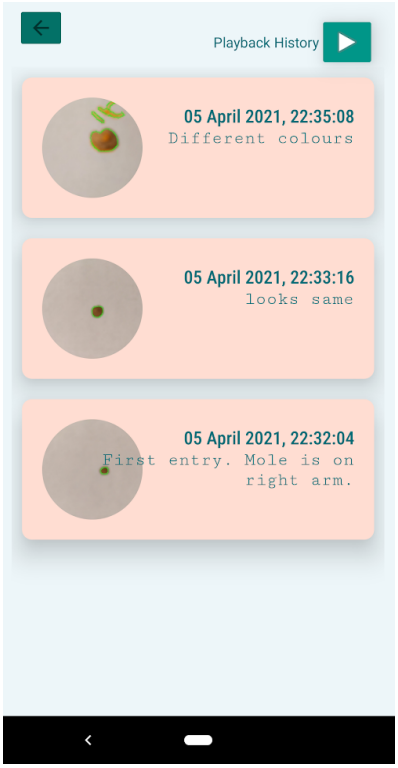


Figure 3

Viewing Previous Records

Through the history feature, users can see each of their previously recorded moles. The moles themselves are organized by names which can be seen in Figure 4. Selecting a mole allows you to see every previous entry of that mole (Figure 5). Tapping on the entry will show you the additional responses from the questionnaire that were stored (Figure 6). Since changes in moles can be subtle, there is also a time-lapse feature incorporated.





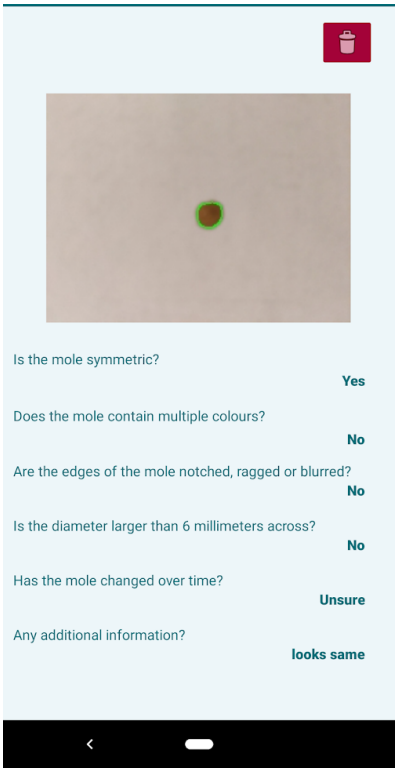


Figure 4 **Figure 5** **Figure 6**

The time-lapse feature can be accessed through the ‘Playback History’ button, as seen in Figure 5, and allows the user to see how their mole has evolved over time. It starts by displaying the first recorded entry of that mole. It then transitions to the following image. By displaying all the images in a sequence and at regularly timed intervals, users can visually observe the difference between their first entry and their most recent entry for the corresponding mole. Figures 7-9 would together show a full time-lapse.

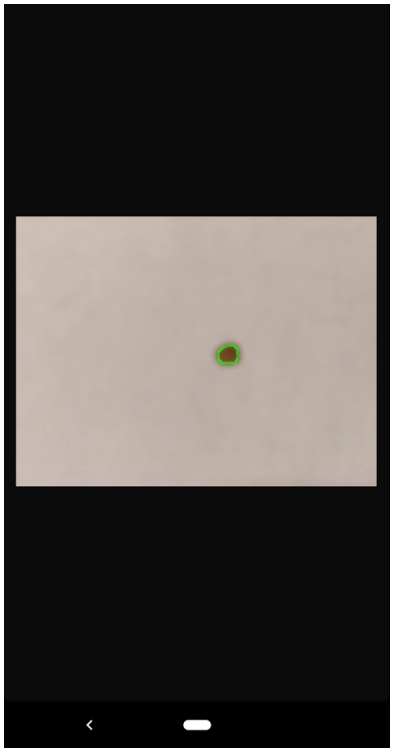


Figure 7

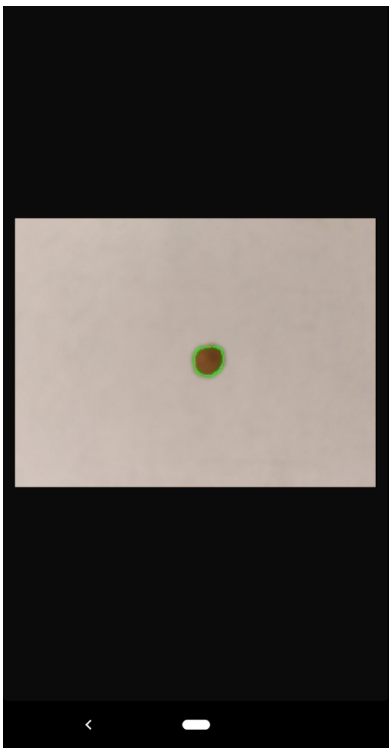


Figure 8

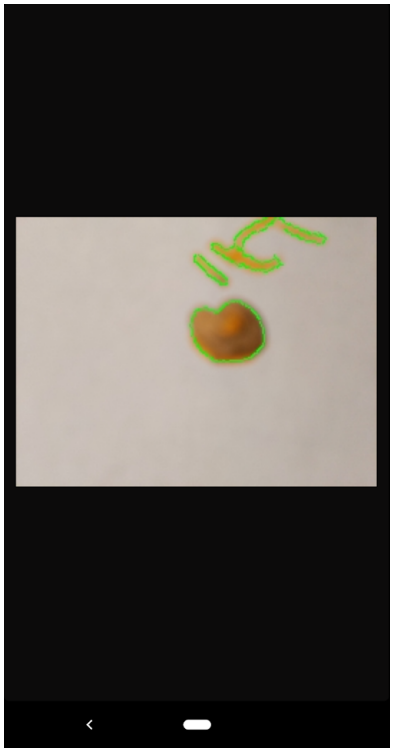


Figure 9

Adding a Physician

The application supports a user adding an authorized physician to their account. Adding a physician would give them access to a user's mole images and questionnaire answers (shown in more detail in future sections and Figure 11-13 below). This was done by users adding a physician ID, which could be copied from the physician's main page with the Copy ID button (Figure 10).

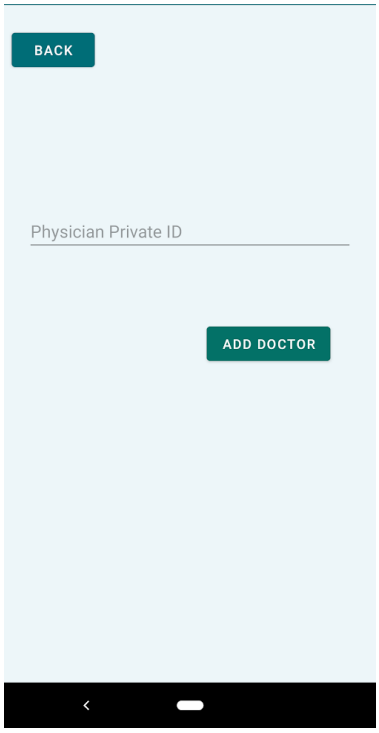


Figure 10

After they have been added, physicians would then have access to their patient's records. From their main pages, they would be able to access a view with the same functionality as the patient's history view described above. This view is shown in detail in Figures 11-13.

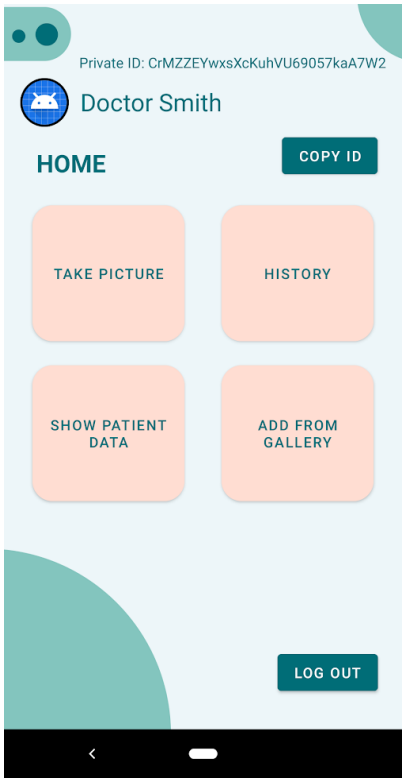


Figure 11

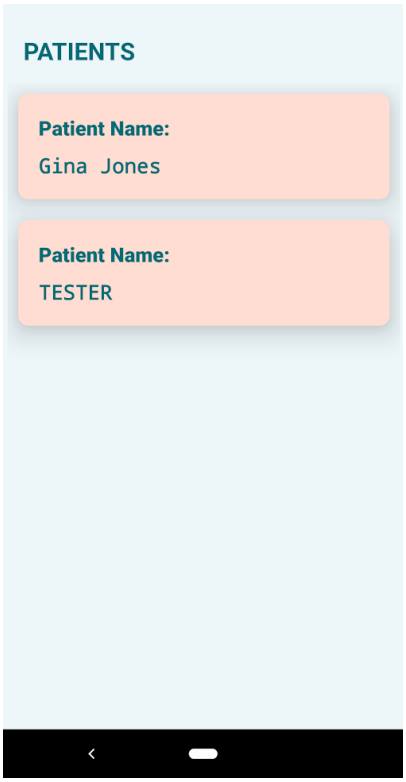


Figure 12

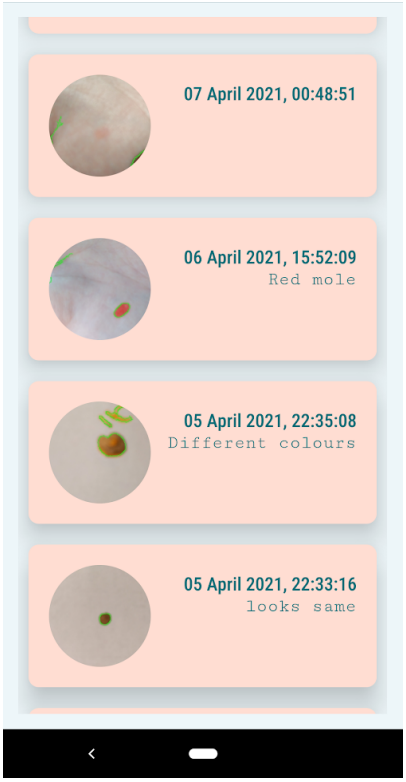


Figure 13

Overall Design

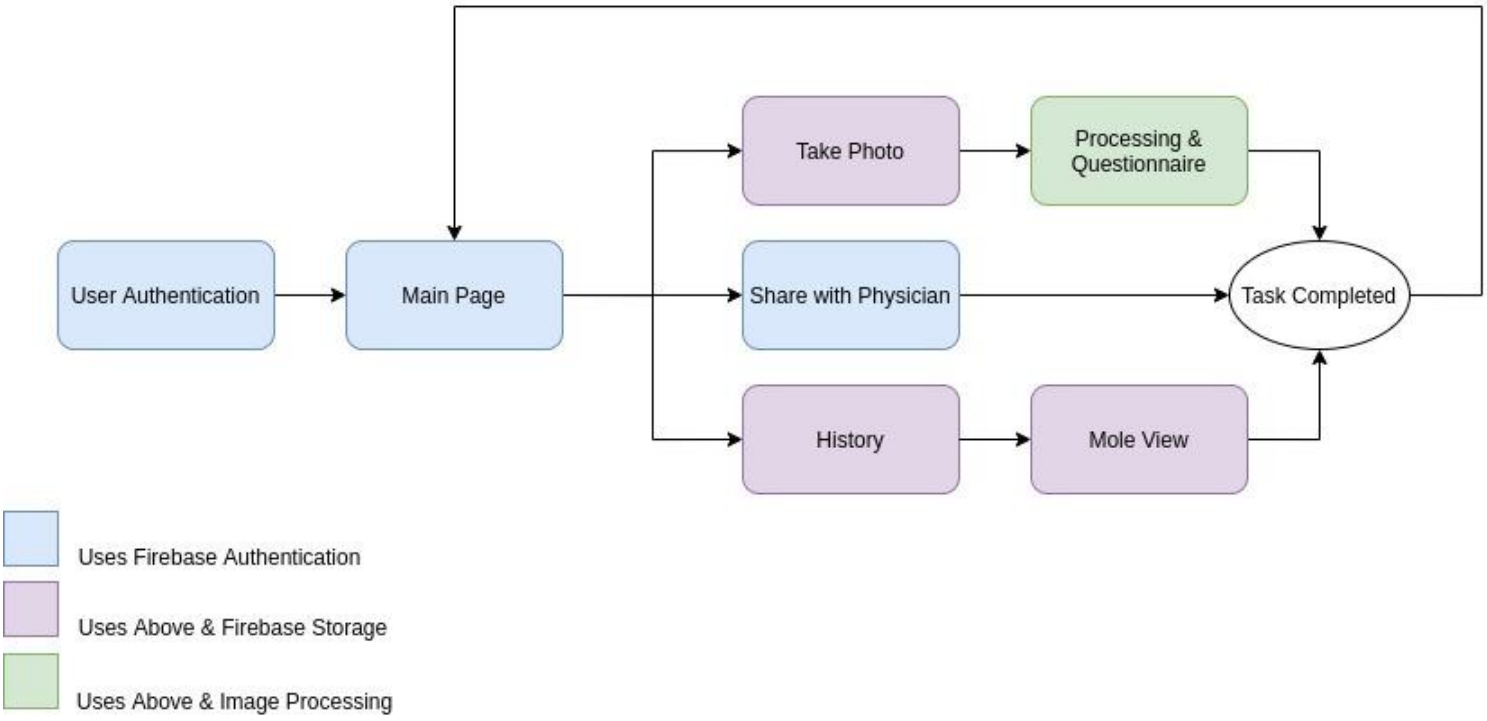


Figure 14: Block Diagram of the Application

The block diagram in Figure 14 above explains the flow of the user within the application. The app's main goal is to allow the user to keep track of moles. To do this, we first authenticate our users so that we can keep track of user data and allow the user to access their data from different devices. This was performed using Firebase Authentication. Then, we take the user to the main page from which they have three main options

1. **Photo Capture**: This feature allows a user to take a photo of their mole. Through the Firestore Database, any previous moles recorded by this user are extracted and their names are presented in a dropdown. The new photo could be tagged to an existing mole, using the unique names from the database, or to a newly created one. After capturing an image, it is processed using OpenCV to isolate regions of interest in the image and perform some analysis to generate suggestions for the questionnaire. The symmetry of the mole is identified using Principal Component Analysis and the size of the mole is calculated based on the area of region of interest (measured in $pixels^2$). The user would then fill out a questionnaire or auto-populate some responses based on our calculations. Then, the image would be saved in our database (Firebase Storage & Firestore), along with the results of the questionnaire for use later.

2. **Sharing**: This feature allows a user to share their user data with an authorized physician. The user must have the physician's ID, which allows us to ensure that only physicians who share their IDs with patients can be added. The physician ID is a unique number created when they register with the application. This ID is added to a list of authorized users who can access the patient's data. The physician would then be able to access their patient data in a patient version of the history view (described in Figure 11-13 above).
3. **History View**: The history view allows them to look at previous moles that the user is keeping track of. These images and results are all pulled from Firebase Storage. The moles are first queried based on the user's unique ID and presented to the user as a list of mole names. Selecting a mole will take them to a "Mole View" (Figure 5), which searches for the user's data associated with that specific mole name and allows them to look at the information on their questionnaire and see all of the images of that mole in a time-lapse (described above).The time-lapse showcases images of the mole from oldest to most recent using a timed transition slideshow. This allows the user to see a mole's evolution over time.

Reflection

One of the things our group found particularly useful during this project was the spiral method we followed. Having set deadlines every two weeks where we were expected to demonstrate parts of our app, forced us to focus on which features were a priority. We had several discussions on this during the proposal stage where we ranked features based on how long they would take to implement and how essential the feature was. As an example, when we began discussing this project, we had ideas on using the app for classifying different types of skin diseases, not just moles. However, we agreed that classifying skin conditions would be challenging and may require a lot more time and effort with minimal results. Thus, we switched our focus to tracking moles. We then further prioritized getting computer vision functionality in our application as that was essential to our goal. Having a minimum viable product early on also gave us a chance to test out the app and to make changes based on feedback.

We also learned about designing user interfaces differently depending on the target audience. For example, when we decided to add a Physician page, we had to choose how the features and information presented would vary between patients and physicians. The primary reason for this was because users might like to see certain information about their moles, like when it was last recorded and how it has evolved over time, while a physician might be more concerned with the most recent post and if it might depict signs of being malignant.

Through our own projects and learning about the work done by other groups, we learned about a lot of the different functionalities that are available on mobile phones. If we were to do this project again, we would look into how we could use some of these built-in sensors to improve

the accuracy of our own application. For example, currently, we estimate the size of a mole based on the assumption that the user is holding their phone 5cm away from their mole. However, for higher accuracy, we could use the accelerometer or LIDAR sensors to perhaps measure how far away the device is.

Contribution Distribution

Aleksei Wan (Programmer)

- Implemented initial skeleton functionality & UI views (e.g. authentication, Firebase infrastructure, image capture) based on programmer assignments
- Created image processing, suggestion generation (for auto-populating fields), and physician alert functionality
- Created physician management infrastructure & features
- Tested application functionality & minor UI improvements

Najah Hassan (Programmer)

- Built the UI for viewing a log of recorded moles
- Built the UI for showing the transition of a mole over time
- Integrated the feature of naming a mole, tracking an existing mole, or recording a new one
- Implemented UI designs on the home page based on Marvel designs
- Built pages for viewing patients and patient data through the Physician View

Neall Struwig (Specialist)

- Provided the app idea that guided the programmers in their work and tested it to ensure it was within my vision
- Created the user interface mock-ups by using the Marvel app
- Provided the questionnaire that would alert users if a mole could be cancerous
- Helped with implementing the user interface of the app by converting the code from the mock-up to android studio

Specialist Context

As a Biomedical Engineering student, my expertise lay within the combination of healthcare and technology. More specifically, my skills are within medical imaging and product development. Trying to combine these fields into an app, Track-a-Mole was created. Based on my experience in the field and talking to other experts, there seems to be a need for an app such as Track-a-Mole. Moreover, my market research showed that of skin health apps, there are not many apps on the market such as Track-a-mole. The development of Track-a-Mole has allowed me to combine my expertise in medical imaging and product development in a practical setting.

Taking the idea of Track-a-Mole into the far future, I could see general practitioners and dermatologists recommend the app to their patients. Also, patients might download it from the App Store or Play Store and ask their doctor to add themselves to the app. I believe this would increase the rates of stage 1 and 2 skin cancer, but decrease the rates of stage 3 and 4 skin cancer. In other words, the app would lead to earlier detection of skin cancer. In turn, this could lead to a lower mortality rate from skin cancer and indirectly save lives. However, in the short term, the app and this course have shown me the great capabilities a phone can have. This will influence my work and research in that I will try to move my specialties to the mobile environment when possible.

Future Work

Our group has worked hard to develop a useful mobile app that can help many people. However, given the time constraints of building an application in a course, the app still has room to grow. As potential future updates, we would like to include more features such as an improved doctor-patient integration system, data exportation, UI/UX design, and a classifier.
The doctor-patient integration is currently a bit rudimentary, so we would like to make it more elegant. We plan on achieving this by authorizing a doctor-patient relationship through Bluetooth. This means when the patient sees their doctor, they can use Bluetooth to give access so the doctor can see the patient's data.

Data exportation would be a useful addition to Track-a-Mole because it allows the user to send their data in an encrypted format to a person. This will allow the user to selectively send their data to a doctor, close friend, or family member as a one-off rather than giving full access to a user's data. This would make getting a second opinion from a specialist much easier and faster.

We believe that the UI and UX of the app are good so far, but we would like to still improve on it. Having more animations in the app will make it feel more 3D and pleasant to the eye. Additionally, instead of having the user type the location of their mole into the textbox, we would like to have the user tap the location of their mole on a human diagram. This will make it easier for the user to know which mole they are taking a picture of when updating their mole's condition.

Lastly, a classifier would make the analysis component of the app even better. A classifier may be able to tell if a mole is cancerous with higher accuracy, as compared to a questionnaire alone. While the classifier will still not take over the role of a physician, it may still yield additional insights and give the user/physician more data to consider. Furthermore, the classifier could also be trained on other skin conditions, but that would be outside the scope of the app (and would likely lead to a change of the app name).

Statement of Consent

I hereby provide my consent to have the following posted publicly:

	Aleksei	Najah	Neall
Final Presentation Video	Yes	Yes	Yes
Report	Yes	Yes	Yes
Source Code	Yes	Yes	Yes

References

[1]“Skin conditions by the numbers,” American Academy of Dermatology. [Online]. Available: https://www.aad.org/media/stats-numbers. [Accessed: 02-Feb-2021].

[2] “Skin Conditions,” Canadian Dermatology Association, 14-Jun-2018. [Online]. Available: https://dermatology.ca/public-patients/skin/skin-conditions/. [Accessed: 02-Feb-2021].

[3] "Stage 4 Melanoma", Melanoma Research Alliance, 2021. [Online]. Available: https://www.curemelanoma.org/about-melanoma/melanoma-staging/stage-4-melanoma/ . [Accessed: 17- Apr- 2021].