# Using AI and Polarized Imaging to Assist Physicians With Early Skin Cancer Diagnosis

## Introduction

Skin cancer is the most common type of cancer worldwide, and more than two people die from skin cancer every hour (Rogers, Weinstock, Feldman, and Coldiron, 2015). Melanoma is the deadliest type of skin cancer, and is the leading cause of 83% of skin cancer-related deaths (Tannous, Al-Arashi, Shah, and Yaroslavsky, 2009). In order to increase the chances of successful treatment, it is paramount that efforts are made by a physician to accurately diagnose melanoma and other skin-related cancers in a patient before they metastasize (Apalla, Nashan, Weller, and Castellsagué, 2017).

Artificial intelligence models are currently under development to detect melanoma and other skin cancers in their early stages, and the most cutting-edge algorithms can classify validated datasets at ~95 percent accuracy (European Society for Medical Oncology, 2018). However, this is only the case if the data is captured under optimal circumstances for maximal clarity (American Academy of Dermatology, 2019); it would be difficult for classifiers to correctly identify unclear images of skin lesions, regardless of how accurate the model is in practice. In addition, since near-dermatologist-level classifiers are trained using clinical datasets to recognize skin lesions from dermoscopies (Esteva *et al*. 2017), one would need to take pictures of skin lesions using dermoscopic imaging techniques to obtain the best result from the classifier.

One such imaging technique, known as polarized dermoscopy, uses a polarized light source and magnifying optic, decreasing glare while also increasing the visibility of structures in the deep dermis (Louie *et al.* 2018). The light emitted from the source is first polarized linearly by a filter. When this light contacts the skin, a portion of it is reflected by the *stratum corneum* (the outermost layer of the epidermis), but the remaining light penetrates through and illuminates deeper layers of the dermis. In a process known as *randomization of polarization* (Dimitriou, Scope, Braun, Reiter, and Marghoob, 2019), a portion of the light is then backscattered in a perpendicular orientation. The backscattered light is subsequently allowed to pass through a polarizing filter in front of the optic, which has been positioned orthogonally to the light source's polarizing filter. The filter blocks out the light reflected by the *stratum corneum*, but allows light reflected by the deeper layers to enter the optic for viewing, due to its polarization (Pan *et al.* 2008). The filtering of light reflected from the *stratum corneum* reduces glare, and allows the optic to view up to 1 millimeter below the *stratum corneum*, revealing the underlying pigmented structures and blood vessels (Rosendahl and Marozava, 2019). Some polarizing-specific skin structures also become more apparent with polarization, such as white spots that appear in basal cell carcinoma (Rosendahl and Marozava, 2019), as well as white lines, which may hint at the presence of melanoma or dermatofibroma (Cohen, Elpern, Wolpowitz, and Rosendahl, 2014). Without the use of polarization, these structures are not visible. Another advantage to using polarized dermoscopy over non-polarized dermoscopy is that polarized dermoscopy does not require direct contact with an immersion fluid on the skin to get a clearer image (Rosendahl and Marozava, 2019).

There are two purposes of this project: the first is to create a system that will assist physicians in accurately diagnosing skin lesions. The system will consist of an artificial intelligence model that classifies skin lesions, a custom polarizing light device, and a web application interface. The artificial intelligence model will be trained using the publicly available Harvard *HAM10000* (*Human Against Machine with 10000 training images*) clinical dermoscopic dataset. Included in the *HAM10000* is an image set known as the Australian Rosendahl image set, which uses pictures of skin lesions, many of which have been obtained by polarized dermoscopy methods (Tschandl, Rosendahl, and Kittler 2018). After the model has been created, it will be integrated into the web application interface, which will allow it to be accessible from a smartphone web browser. A custom polarizing light device (from here on referred to as the *Polarizer Device*) will be created, designed to be attachable to a smartphone. Its function is to grant the smartphone's camera polarized-imaging capabilities for capturing skin lesions, in order to emulate non-contact, polarized dermoscopy techniques. As a tool for physicians to use, the artificial intelligence web application may be configured to upload its diagnoses of skin lesions into the physician's electronic medical record of choice, such as the McMaster *OSCAR Electronic Medical Record* (a popular open-source electronic medical record used by thousands of doctors across Canada), for maximum efficiency and convenience. These products in the system are designed to be used in tandem with each other: the physician will use their smartphone with the Polarizer Device to capture polarized light images of a patient's skin lesion, and through the web application, the physician can easily upload the image to the artificial intelligence model, which will analyze the lesion and provide its own diagnosis. Then the model will pass the image and analysis results directly into the patient's file on the physician's electronic medical record.

The second purpose is to investigate whether or not the accuracy of the artificial intelligence model is improved when classifying images captured by the smartphone with the Polarizer Device as opposed to regular, non-polarized images taken without the Polarizer Device. As the artificial intelligence model has been trained to recognize images of polarized skin lesions, it is expected that it would classify pictures taken using polarized imaging techniques more accurately than non-polarized skin lesions.

This innovation may become the impetus for a real-world product for use in a primary care setting, so that physicians are provided with a "second opinion" from this safe and easy-to-use system, reducing the chances of misdiagnosis when assessing a skin lesion. This will potentially save many patients' lives, as skin cancers are best treated when diagnosed early (Canadian Cancer Society, n.d.).

# Hypothesis

It is hypothesized that by using polarized imaging to take pictures of skin lesions, the performance of the artificial intelligence classifier will improve significantly. As the model has been trained to primarily recognize polarized images due to being trained using the *HAM10000* dataset, it is hypothesized that it would more accurately classify images that have been captured using the smartphone with the Polarizer Device.

# Procedure

The project's procedure has been segmented into four distinct parts; the first two involve creating the infrastructure (the Polarizer Device, artificial intelligence model, and web application interface) required to streamline data collection and analysis from the experimentation. The third part is the data collection for evaluation of the Polarizer Device. The fourth and final part of the procedure involves creating test patient profiles to observe if the web application works as intended if configured to be used with an electronic medical record system, for real-world application.

*Part 1: Creating the Polarizer Device*

To conveniently obtain polarized images of skin lesions, an easily mountable custom polarizing light device will be created for a smartphone (Google Pixel 3A). The device will be composed of an LED light source, and have two intermediary linearly polarizing filters, positioned perpendicular to each other. The device will be made attachable to the smartphone. One of the filters will fit in front of the smartphone's camera, while the other will fit in front of the light source. The device must fulfil the following requirements:

- Filters must be easily removable
- Filters must be easily positionable
- Light source and camera must be joined together as one unit
- Device can fit on most smartphones, regardless of manufacturer
- Device is easily removable from the smartphone

I have already made a 3-D schematic for the Polarizer Device that complies with all the specifications, and I plan on making a 3-D printed prototype model of it.

*Part 2: Artificial Intelligence Model and Interface*

A machine learning classifier has already been built by myself, using the artificial intelligence open-source software library, Google TensorFlow, and trained with data from the aforementioned Harvard *HAM10000* skin lesion dataset. The artificial intelligence model uses the Adam Optimization Algorithm (Kingma and Ba, 2014). I have written a Python program to read the model, and have implemented the Python program into a web application. The web application has been written using an HTML frontend, and an image upload program was created using PHP. This web-based infrastructure allows a user to easily upload pictures from a web browser, such as a browser on a smartphone. The web application will securely pass the picture to the artificial intelligence model for analysis, and display the results of the model's diagnosis. The hardware used for all of the infrastructure is an Intel i5 hexcore PC running Ubuntu Linux.

*Part 3: Data Collection*

With the required infrastructure created and ready to use, data collection of images of skin lesions is now simplified. A qualified physician will use a Google Pixel 3A smartphone with the Polarizer Device to capture images of consenting participants' skin lesions at their clinic, both with and without light polarization. The images will be taken in a dark room; the light from the Polarizer Device will be the only source of light. All pictures taken of skin lesions will be anonymous; they will have no identifiable information attached to them such as names, phone numbers or patient chart numbers, and there will be no identifiable features in the picture such as faces or tattoos etc.

*Part 4: Web Application Interface Test*

The final part of the procedure is for testing the web application interface. The application will be configured to upload the results of the data analysis to an *OSCAR Electronic Medical Record* system. For use as a final product in a primary care setting, the option to include metadata such as patient chart numbers can be implemented for real-world physician use. To observe if this configuration works as intended, fake patient files will be created, with false patient chart numbers and other information. To protect the privacy of participants, no images from participants will be used to test the web application interface. Miscellaneous images of skin conditions found on the public domain will be used, and uploaded to the algorithm via the interface, with fabricated metadata attached. If the algorithm analyzes and passes the image and diagnosis to the fake patient's file successfully, then it will be concluded that the interface works as intended for a real-world application.

# Results and Interpretation

From the data collected in *Step 3* of the procedure, both the polarized and non-polarized data will be uploaded to the artificial intelligence model via the web application, and the model's diagnosis will be recorded. The diagnosis from the artificial intelligence model consists of seven different diagnoses: melanoma, basal cell carcinoma, actinic keratosis, benign keratosis, vascular skin lesions, melanocytic nevi, and dermatofibroma, with a confidence percentage for each classification. For each skin lesion, the result of the artificial intelligence model's diagnosis for both the polarized and non-polarized image will be compared with the diagnosis of the skin lesion from a family doctor, dermatologist, or pathologist diagnosis, to determine under which polarization circumstances the model was more accurate in its classification.

# Human Participants Research

Human participants who will take part in this project will be patients found in a physician's clinic. They will have images of their skin lesions captured using both polarized and non-polarized light by the physician himself during their skin examination, using the Polarizer Device. The length of time required for each participant is around two minutes, and no subsequent commitment is needed after the lesions are captured. It is expected that they will be from all ethnical backgrounds and genders, and their ages will range from 18 to 100 years old; no minors will take part in the data collection. There are also no vulnerable populations that will take part in the data collection. Every participant must sign a consent form that states that a picture of their skin lesion will be used for this project. However, their identity will remain completely anonymous, as all pictures taken of skin lesions will have no personal data attached to them such as their names, phone numbers or patient chart numbers, and there will be no identifiable features in the picture such as faces or tattoos etc. All images will be cropped so that only the skin lesion and a comparatively small portion of the surrounding skin will be visible.

# Risks, Safety, and Privacy

There are no physical, psychological, social, or legal risks or discomforts for any humans involved in the project. Every participant involved in the project must sign an informed consent form that states that a picture of their skin lesion will be used. They will be explained the purpose of the data collection, and reassured that their identity will remain completely anonymous. To guarantee complete anonymity, none of the skin lesion pictures will have any patient information attached to them (i.e. patient names, phone numbers, patient chart numbers, etc.) and precautions will be taken to ensure that there are no identifiable features in the picture such as faces or tattoos. Skin lesions will be captured using a smartphone camera with the Polarizer Device attached. Data will be uploaded and stored in the researcher's password-protected computer via a web application running off of a secure local network. Images taken with the smartphone camera will be subsequently deleted after their upload. None of the obtained data will be used to train the artificial intelligence model itself. After the experimentation and analysis is complete, all of the data will be erased from the computer. Permission forms will be stored securely and shredded at the conclusion of the science fair. Participants have the right to opt out of data collection at any time for any reason, and they may also request an anonymous summary of the project's results after the conclusion of the science fair, via email. All of this information will be communicated to the patient through the *Letter of Information*, and I, the researcher, will do my best to answer any questions participants may have to their satisfaction before they agree to be involved in the project.

# References

Rogers, H. W., Weinstock, M. A., Feldman, S. R., & Coldiron, B. M. (2015). Incidence Estimate of Nonmelanoma Skin Cancer (Keratinocyte Carcinomas) in the US Population, 2012. *JAMA Dermatology, 151*(10), 1081. doi: 10.1001/jamadermatol.2015.1187

Tannous, Z., Al-Arashi, M., Shah, S., & Yaroslavsky, A. N. (2009). Delineating melanoma using multimodal polarized light imaging. *Lasers in Surgery and Medicine*, *41*(1), 10–16. doi: 10.1002/lsm.20736

Apalla, Z., Nashan, D., Weller, R. B., & Castellsagué, X. (2017). Skin Cancer: Epidemiology, Disease Burden, Pathophysiology, Diagnosis, and Therapeutic Approaches. *Dermatology and therapy*, 7(Suppl 1), 5–19. doi:10.1007/s13555-016-0165-y

European Society for Medical Oncology. (2018, May 28). *Man Against Machine: Artificial Intelligence is Better than Dermatologists at Diagnosing Skin Cancer [Annals of Oncology Press Release]*. Retrieved December 9, 2019, from https://www.esmo.org/Press-Office/Press-Releases/Artificial-Intelligence-Skin-Cancer-Diagnosis.

American Academy of Dermatology. (2019, March 1). *Artificial intelligence shows promise for skin cancer detection*. Retrieved December 9, 2019, from https://www.aad.org/news/ai-and-skin-cancer-detection.

Esteva, A., Kuprel, B., Novoa, R. A., Ko, J., Swetter, S. M., Blau, H. M., & Thrun, S. (2017). Erratum: Corrigendum: Dermatologist-level classification of skin cancer with deep neural networks. *Nature*, *546*(7660), 686–686. doi: 10.1038/nature22985

Louie, D. C., Phillips, J., Tchvialeva, L., Kalia, S., Lui, H., Wang, W., & Lee, T. K. (2018). Degree of optical polarization as a tool for detecting melanoma: proof of principle. *Journal of Biomedical Optics*, *23*(12). doi: 10.1117/1.JBO.23.12.125004

Dimitriou, F., Scope, A., Braun, R. P., Reiter, O., & Marghoob, A. A. (2019). Polarized dermoscopy. *dermoscopedia*. Retrieved 03:03, December 9, 2019 from https://dermoscopedia.org/w/index.php?title=Polarized_dermoscopy&oldid=15355.

Pan, Y., Gareau, DS., Scope, A., Rajadhyaksha M., Mullani NA., Marghoob AA.. Polarized and Nonpolarized Dermoscopy: The Explanation for the Observed Differences. *Arch Dermatol*. 2008;144(6):828–829. doi:10.1001/archderm.144.6.828

Rosendahl, C., & Marozava, A. (2019). *Dermatoscopy and skin cancer: a handbook for hunters of skin cancer and melanoma*. Banbury: Scion Publishing Limited.

Cohen YK, Elpern DJ, Wolpowitz D, Rosendahl C. Glowing in the dark: case report of a clue-poor melanoma unmasked by polarized dermatoscopy. *Dermatol Pract Concept*. 2014;4(1):83–87. Published 2014 Jan 31. doi:10.5826/dpc.0401a14

Tschandl, P., Rosendahl, C. & Kittler, H. (2018). The HAM10000 dataset, a large collection of multi-source dermatoscopic images of common pigmented skin lesions. *Sci Data 5*, 180161 (2018) doi:10.1038/sdata.2018.161

Canadian Cancer Society. (n.d.). *Finding skin cancer early*. Retrieved December 9, 2019, from https://www.cancer.ca/en/cancer-information/cancer-type/skin-melanoma/finding-cancer-early/?region=bc.

Kingma, D. I. P., & Ba, J. (2014). Adam: A Method for Stochastic Optimization. *Adam: A Method for Stochastic Optimization*. Retrieved from https://arxiv.org/abs/1412.6980

# Acknowledgements

I would like to thank my science teacher, Mr. Henri van Bemmel, my adult sponsor, who guided me through the project and the application process.