Title of Project: **Building DeepSkin: a low-cost state-of-the-art digital dermatoscope.**

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Team: **Steve Smith** (sps41@cam.ac.uk). A clinical dermatologist with experience in computational image analysis and modeling. Project lead and coordinator, will put the project in a clinical context as well as coding, building and designing the dermatoscope.
Youssef Badr (yaab2@cam.ac.uk). Reading Chemical Engineering in the Department of Chemical Engineering and Biotechnology. Will lead on the electronics work and provide engineering expertise.
Joseph Wu (jw895@cam.ac.uk). PhD candidate researching the early diagnosis of cancer with research background studying the genetic regulation of skin cancer. Will ensure the project is consistent with recent advances in the biology of skin cancer and formally analyse cost-effectiveness and diagnostic accuracy.

Summary

Skin cancer is the most common cancer in the world. Clinical diagnosis of skin cancer is made by dermatologists using an instrument called a dermatoscope which enables close-up visualization of the skin. Dermatoscopes are expensive and require clinical expertise for use in daily practice. Sharing dermatoscopic images remotely can allow non-dermatologists collaborate with experts elsewhere, but the cost and limited availability of digital dermatoscopes prevents this from happening routinely. We will develop DeepSkin, a hand-held, portable and easily understood digital dermatoscope that is cheap, simple and capable of storing and transmitting dermatoscopic images.

Gold standard skin imaging techniques use multispectral and polarimetry data to supplement plain image analysis, but the equipment to do this is expensive and bulky. DeepSkin will be able to analyse skin lesions in multiple spectra from ultraviolet to near-infrared and in multiple polarities. Despite its advanced capabilities this will cost orders of magnitude less than legacy equipment used at present.

Proposal: The Problem

Skin cancer is the most common cancer in the world, with more new cases of skin cancer each year than all other cancer types combined. **Early diagnosis of skin cancer is critical** - moles and other skin lesions are common and hard to diagnose by eye alone so many benign growths are removed unnecessarily or ignored for too long, allowing cancers to grow and spread. These impact on patients and impose an enormous burden on health services and professionals.
Dermatologists currently use an instrument called a dermatoscope to enable them to get a close-up view of skin problems. These instruments use a magnifying lens with polarised illumination to give a detailed close-up view of a skin lesion. **Even the cheapest of these retail for £150 or more** – and these simple dermatoscopes do not record images, limiting their users to making real-time decisions. If dermatoscopic images are shared then experts can be consulted remotely, enormously expanding the utility of these tools. Digital dermatoscopes do exist but are even more expensive and rarely used.
Standard dermatoscopes view the skin through one polarised light and a simple magnifying lens. **Multispectral imaging** of skin tumours increases diagnostic accuracy of dermoscopy and **polarised light analysis** reveals specific diagnostic information about cancers that plain light cannot. Both ultraviolet and near-infrared imaging of skin lesions have been shown to be diagnostically important in diagnosing skin conditions. Spectroscopy and polarimetry equipment have been built and used to research the diagnosis of skin cancers, but the equipment is immobile, bulky and extremely expensive (often tens of thousands of pounds).
As a result **these techniques are not used in routine clinical practice**. The only spectrometry-enabled dermoscopy technique in routine practice, the SIAScope, has been moderately commercially successful despite being limited to a narrow set of spectral wavelengths, not including polarimetry and costing a minimum of £2500. This device remains the gold standard in non-invasive melanoma diagnosis despite those limitations and as a result of them has been shown to be limited to only that subset of skin cancers.
There is a clear need for a cheap, widely available and accessible dermatoscope which can record images.
There is also a clear need for an imaging instrument that uses multispectral and polarimetry data in a platform that can used in an everyday clinical setting, including in resource poor settings.

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Our Solution

Design goals:

DeepSkin, a new digital, multispectral and polarimetry enabled dermatoscope will be:

- Hand-held, portable and light for daily, extended use.
- Able to operate as a digital light dermatoscope in daily practice.
- Capable of advanced multispectral and polarimetry analysis for clinical and research use.
- Robust and sealed for safe use in clinical settings.
- Able to transmit and save data for off-platform analysis and research.
- Cheap, open source and simple to use, ensuring wide access.

Implementation

To prototype DeepSkin we will combine the **Raspberry Pi NoIR camera** with control hardware, initially via a Raspberry Pi 3 board, and to move towards a production-ready system an Arduino control board. The camera will be used to image through a simple Loupe triplet lens via a pair of **mechanically controlled filter wheels**. Each wheel will be 3D printed initially (eventually aiming for plastic moulded) and contain either spectral or polarising filters to enable all possible combinations of spectral/polarised light imaging. The wheels will be controlled by servos timed to rotate in sequence with the NoIR camera imaging, acquiring approximately 50 images in full analysis mode.

A ring of **LEDs** will illuminate the field of view and give optimal reflectance for spectral/polarimetry imaging. We will include **bright white (mixed spectrum), ultraviolet and infrared** LED sources in the illumination ring. A **touch screen interface** will be used to visualise lesions in simple mode, save/send images and initiate advance analysis mode. **Wireless** (Wifi/Bluetooth) communication will allow for sending of images to external hardware (PC/mobile/tablet etc). Rechargeable batteries will enable wireless use and a light **3D printed chassis**, filter wheels and structural support will ensure that the device is **light and portable**, as well as sealed and **able to be cleaned for clinical use**. As we move from prototype to finished product the components we use will be widely available to maximize the scalability and opportunity for adoption of the technology in a wide range of economic settings.

Proposed outcomes and benefits.

- *Primary outcome:* **An open-source, low-cost digital dermatoscope suitable for widespread use.**
- *Benefit*: Increased access to gold-standard diagnostic equipment to overcome the rate-limiting step in early skin cancer diagnosis - expertise.
- *Secondary outcomes:* **An accessible, clinically relevant tool for advanced and experimental investigation into the optical characteristics of skin and skin cancers.**
- *Benefits*: Enabling the advancement of the fundamental understanding of carcinogenesis and cancer progression. Improving the ability of primary and secondary care clinicians to make early diagnoses of skin cancers. Accelerating development of computational image recognition approaches in skin cancer, potentially acting as a foundation for new fields of dermatology research.

Appendix I

Estimated components and budget

Component	Total Cost (£)	Part #
Raspberry Pi 3 boards x2	33	CPC: SC14012
Raspberry Pi NoIR cameras x 2	25	CPC: SC14029
Magnifier lenses (10X triplet loupe lens, 20mm) x2	20	Theloupestore: 1210161
Spectral filters: IR cutoff	19.13	Edmundoptics: #49-087
UV cutoff	11.48	Edmundoptics: #39-426
UV/IR Bandpass	23.38	Edmundoptics: #48-630
Polarising filter, wire grid linear	34	Edmundoptics: #34-251

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LEDs (white, UV, IR, 450 nm, 545 nm, 660 nm) 20 each	4	CPC: SC11566
	6	CPC: SC07651
	4	CPC: SC08233
	5	CPC: SC11539
	5	CPC: SC07717
	10	RS: 890-5650
3D printing (chassis, lens support, board mounts, camera mount, filter wheels)	TBC	Media Studio
Servos for filter wheels x2	15	CPC: SC13150
Batteries (LiPo)	18	Pimoroni: BAT0008
LiPo charger module + supply	10	CPC: SC14243
	20	Pimoroni: ADA2465
Bluetooth dongle	10	CPC: CS27894
Touch Screen	35	CPC: SC13541