

Photographic Sciences Capstone

Creating a Low-Cost, Portable, Non-Mydriatic Fundus Camera

Research Paper

Daniel Beim

Abstract

Fundus cameras are a key part of any ophthalmic practice's equipment, as they can be used to locate and document a variety of ocular defects with relative ease. As common as they are though, fundus cameras are often times bulky and expensive pieces of equipment that may not be feasible for use in smaller offices, preventing many populations who may be at risk from getting the help they need. Additionally, most systems are mydriatic systems which means that they require the patient's eye to be dilated, placing further restrictions on the likelihood of smaller practices investing in a system.

The creation of a low-cost, portable, non-mydriatic system would allow for the device to become much more accessible, allowing for more practices and organizations to own a device and perform tests to document and diagnose more patients. This is especially important with the worldwide prevalence of diabetic retinopathy, which can occur as a result of uncontrolled diabetes and may lead to blindness if left untreated. The implementation of a low-cost, portable system would allow for at-risk populations to get examined for the defect and determine if they need to seek treatment, helping to reduce the risk of blindness.

My aim is assist this year's Multidisciplinary Senior Design (MSD) team in the creation of their fundus camera system, using my knowledge of ophthalmic systems gathered from my time in the ophthalmic photography class and my co-op this past summer at the Manhattan Eye, Ear, & Throat hospital. I will provide design advice as well as assist in testing the system, acting as an "expert buyer" and evaluating the system's clinical feasibility.

The Problem

A typical fundus camera system costs in the tens of thousands of dollars, and most systems come as part of a larger system consisting of the fundus camera itself attached to a variable height table which is also attached in some way to a computer system to store data. These systems can be out of the realm of possibility for practices and organizations with limited budgets and space or who are mobile. On top of size and pricing constraints, many fundus cameras require the patient to be dilated which can cause additional hardships with budget as well as with patients who may not want to undergo the dilation process. The need for dilation with many systems creates further complications due to the risk of patients having a contraindication related to increased intraocular pressure, which could be deadly. There are a variety of non-mydriatic systems currently on the market in order to try and circumvent this risk, however the issue of price and sometimes weigh still remain. Due to these factors, fundus systems are not always available and many people with conditions like diabetic retinopathy continue living with the threat of severely decreased vision or blindness.

Current Commercial Technologies

Research into developing newer and more novel fundus imaging systems has been ongoing for many years and has yielded a variety of systems, ranging from miniature systems to smartphone-based devices. I will only cover a small sample of the available non-mydriatic and mobile systems for this paper, in order to give a rough overview of what is currently available to compare to the MSD team's proposed system.

One currently available commercial device is the 3nethra Classic (image 1), which is a lightweight non-mydriatic system capable of color and near-infrared imaging, requiring a

minimum pupil diameter of 3mm and a field of view of 45°. It uses reduced optics to reach its moderate price point of \$7,400, as well as utilizing an infrared light emitting diode (LED) for observation, a white LED as the imaging flash, automatic and manual focus controls, a three megapixel image sensor, and a computer interface for data storage and viewing.^{1 2} The device weighs about 15kg², which is significantly less than a mydriatic system such as the ZEISS PRO NM which weighs 30kg³.



Image 1: 3nethra Classic fundus camera¹

Another commercially available non-mydriatic system is the DRS (Digital Retinopathy System)(image 2), which requires a minimum pupil diameter of 4mm and has a horizontal field of view of 45° and a vertical field of view of 40°. Unlike most systems the DRS is fully automatic, giving it the ability to “sense the patient, self-align to the target eye, focus the retina, adjust the flash level and capture the image in less than 30 seconds.”⁴ The system utilizes white light reflective imaging to capture an image, has a five megapixel image sensor, and utilizes a touchscreen tablet for image capture and storage. The device weighs 19kg and costs about \$10,000, putting it on the higher end of available non-mydriatic systems.^{2 4}

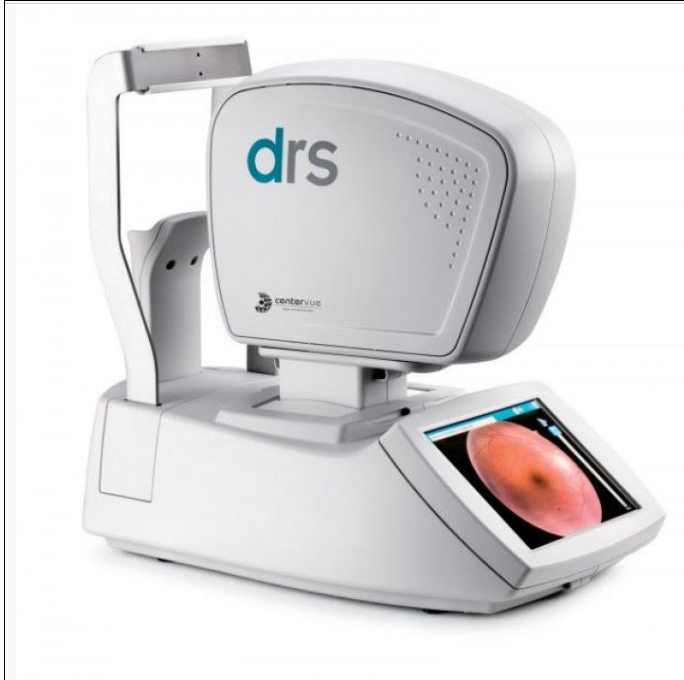


Image 2: DRS fundus camera⁴

The Optomed SmartScope Pro (image 3) is a fully handheld non-mydratic fundus camera capable of color, red-free, and infrared imaging, requiring a minimum pupil diameter of 3.5mm with a field of view of 40°. In addition to being handheld, the device can also fit onto a slit lamp camera mount for imaging. The device can autofocus, has a five megapixel sensor, uses a rechargeable Ni-MH battery, and uses an LCD screen on the back for image viewing but can also be connected to a PC via USB.^{2,5} The devices weight and price are currently unavailable.



Image 3: Optomed Smartscope Pro⁵

The iExaminer and panoptic ophthalmoscope (image 4) are two devices which when combined with an iPhone create a handheld non-mydratic fundus camera capable of color images with a field of view of 25°. ^{2,6} The device's specifications depend on the phone being used, but the panoptic ophthalmoscope portion has a halogen lamp for illumination and a focus

wheel, claiming a “view of the fundus that's 5X greater than you see with a standard ophthalmoscope in an undilated eye.”⁶. The system weighs about one kilogram and costs about \$1,000 plus the cost of an iPhone.²



Image 4: iExaminer and panoptic ophthalmoscope⁶

Previous Academic Work

This will be the third MSD team to attempt to create a low-cost fundus camera, with two other teams having made their own prototypes which they displayed at ImagineRIT in their respective years, passing along their findings to the next year's team to help them develop their system.

The MSD team for 2014-2015 consisted of mechanical engineers Kevin Labourdette and Thomas Casero, electrical engineers Daniel Sui and Quang Huynh, biomedical engineer Ian Morency, and computer engineer Kyle Burden. Together they set out to “develop a prototype of a low-cost fundus camera using off-the-shelf optical components” that could be used without any special training, was portable/compact enough for use in a general practitioner's office, and could take pictures of similarly high quality to those from a commercial system. The team ended up deciding on a standing, vertically adjustable frame model on retractable wheels that the camera mounts to the top of and can tilt so that virtually all patients can rest on the chinrest. The optical system – as seen in image 5 – they created used a 20 diopter lens to magnify the view, a 42 diopter convex lens to increase the angle of view on the retina, and a Raspberry Pi NoIR (no infrared) camera module to capture the images, with a working distance of 40mm and a field of view of 26.5° in a 6mm pupil. The system was able to be focused by moving the camera lens on a stepper motor controlled by the Raspberry Pi, which in turn could be controlled via an attached touchscreen. The system also used an IR LED for focusing and a white LED Bright Pi lamp for illumination of the retina when imaging. The team created a simple application to input patient data using a keyboard plugged into the Raspberry Pi, as well as provide a preview of the camera's current positioning so that it can be properly adjusted and then capture an image when ready. The camera housing design – as seen in image 6 – was designed to be a standing design that allows the patient to sit and lean into it, allowing for it to be a light and collapsible system

for easy storage. The team received some help with deciding on this design from Linda Deng, an industrial design student, and Brittany Bateman, a biomedical photography student. In the end the final product ended up being a rough prototype which was displayed at ImagineRIT, still requiring an improved optics system that cut down on issues like reflections in the captured images but otherwise functional; the project became a proof of concept, showing that it is possible to build a low-cost camera.⁷

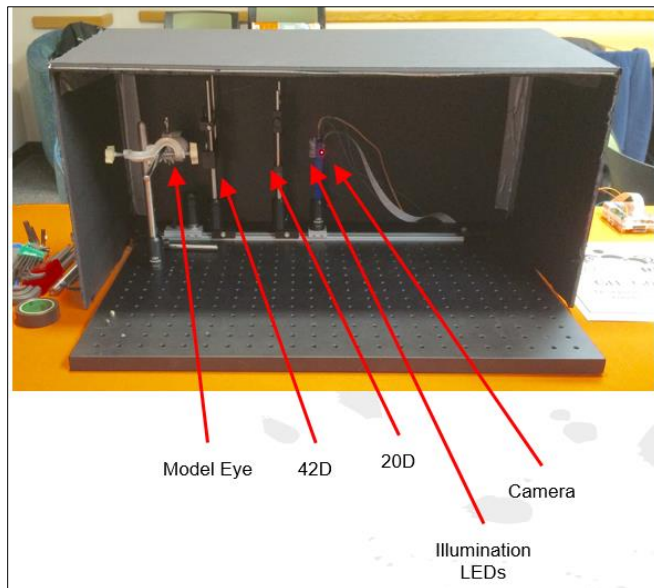


Image 5: The optical system⁷



Image 6: The completed prototype⁷

The MSD team for 2015-2016 consisted of lead software engineer Cecilia Demarest, lead biomedical specialist Kelly Dunn, lead hardware engineer Matthew Little, lead systems engineer Casey Petzel, industrial designer Zachary Olmstead, and lead purchasing and communication specialist Ryan Morgan. Their goals were practically identical to those of the previous team: to create a low-cost, non-mydratic fundus camera that could be used by non-specialized personnel in a general practitioner's office and provides images of similar quality to those from a regular system, in order to attempt to increase the number of screenings for disorders like diabetic retinopathy. The proposed design for the camera was a modular, almost camcorder-like system that could be attached to a variety of base mounts and easily adjustable like a regular fundus system, as well as being detachable for hand-held use (image 7). The camera's optical system – seen in image 8 – utilized a 20 diopter lens as well as a 50mm macro camera lens to image on a four megapixel See3cam sensor system, creating a working distance of 110mm and a 30° field of view in a dilated patient. The system's focusing method appeared to rely on the standard method of using a free-moving base for coarse adjustments and then a joystick within the base for fine-tuning as well as raising and lowering of the camera, similar to how most commercial cameras handle focusing. When the camera is being used handheld, however, the system of focusing

would have been similar, but less precisely controlled as it depends on the stability of the user's hand and the patient. For illumination the system utilized a ring of IR and white LEDs directed down an acrylic tube in order to reduce non-image forming light. In order to capture and process images the system used an ODROID-XU4 single board computer attached to the sensor and lights as well, a solid state drive to store the images, and to an ODROID-VU7 touch screen for viewing and control. The team created an application called FUNdusCam in order to control the illumination and camera, as well as add necessary data to and transfer/save files. The team received some design and lens system as well as clinical setting feasibly advice from biomedical photographic communications student Amber Kates during the design process. In the end the project was largely conceptual, ending up with a functional optical system and a start on the base mount parts but otherwise no real physical prototype.



Image 7: Conceptual housing on base⁸

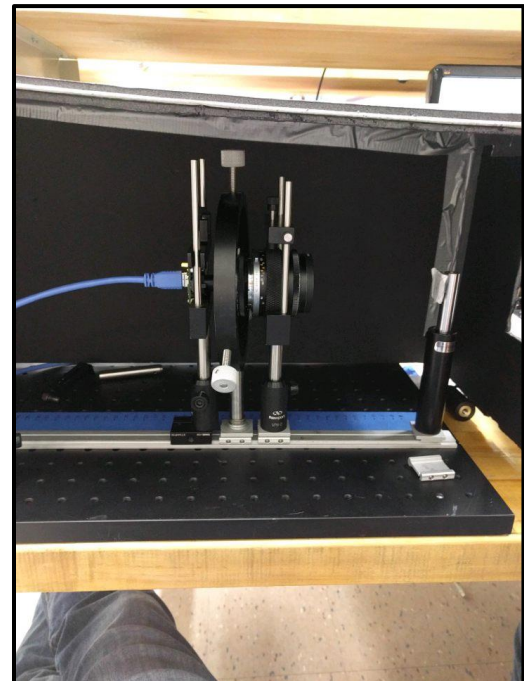


Image 8: Optical system⁸

The Plan

This year's MSD team hopes to continue improving on the systems created by the past two teams to end up with a functional prototype approved for human testing. The project is still in the conceptual stage, but the current plan for components and layout is thus: a miniature tabletop structure with a headrest, IR LEDs for focus illumination, visible/white LEDs for imaging illumination via on-axis "donut ring" illumination, a physical shift device for switching between IR and visible light, reduction of noise caused by reflected light by blocking the center of the light, a pellicle beam splitter, manual adjustment knobs for focusing, a CCD micro-camera for image capture (likely the same one used last year), and a touch screen for image capture and metadata input. As with the previous years' goals, the device is being designed with non-mydratic use in mind as well as an emphasis on portability and a low-cost without sacrificing image quality or comfort. The team is currently working on benchmarking their optics,

reviewing requirements for FDA and human subject research approval, and creating conceptual models, of which the current ideas can be seen in image 9 below.²

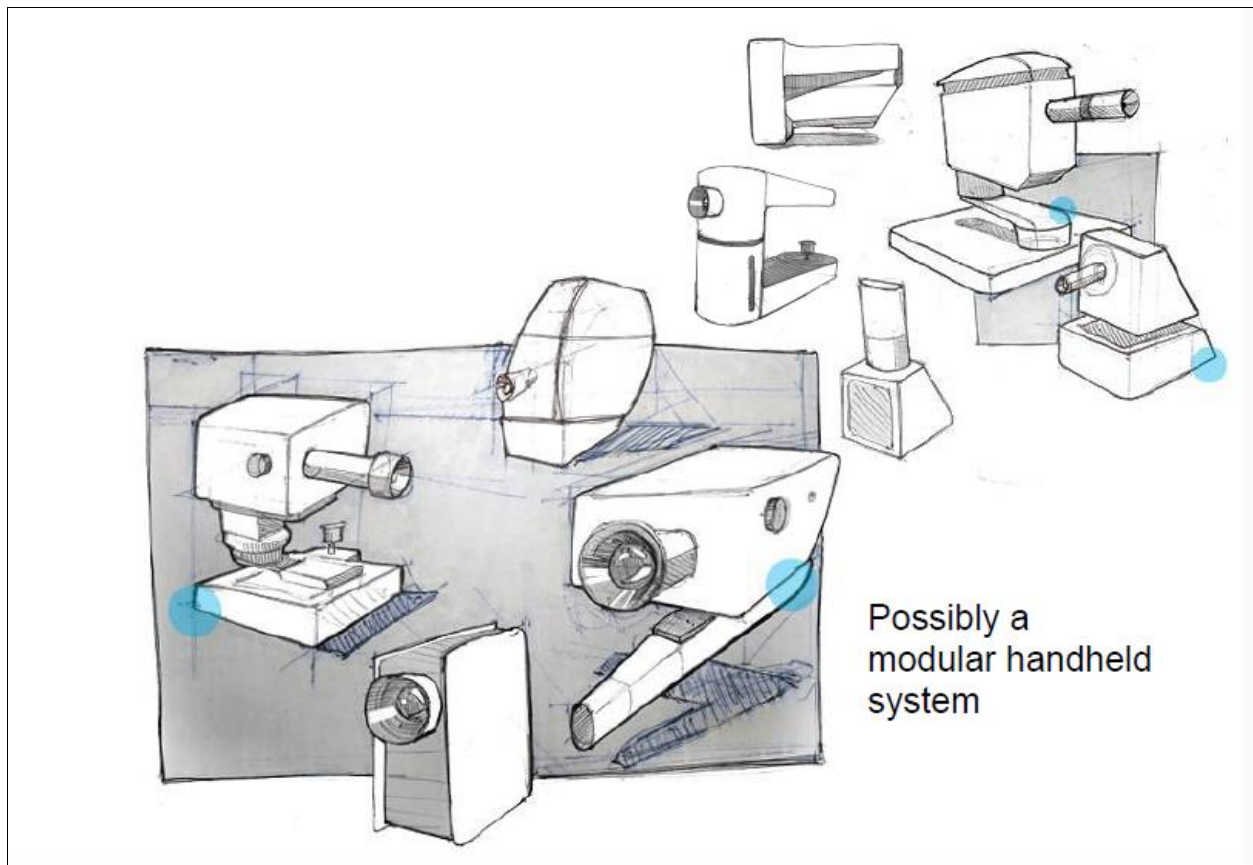


Image 9: Current conceptual sketches²

The previous teams have cited some issues with understanding the optics and other aspects of the system in their final papers, and my goal in joining this year's team is to use my biomedical photography background to help them develop a clinically viable system. I will keep up with the team's progress as they continue designing their system, offering advice on the design and other aspects of the system in a similar fashion to the contributions of Brittany Bateman and Amber Kates with their respective year's team. I also plan to undergo the human subject research approval process myself in the hopes that if a functioning system is developed I can assist in testing it, using my experiences from RIT's ophthalmic photography class as well as my co-op in the ophthalmology department at Manhattan Eye, Ear, & Throat Hospital this past summer. If such testing is possible I will use the opportunity to provide valuable feedback on image quality, ease of use as an operator, and potentially even patient-experience feedback. It will be an enriching experience to see the construction side of the fundus camera, perhaps even leading to further research into the creating of low-cost fundus cameras beyond this project, and I look forward to seeing where it goes.

Mentor Choices

- 1) Christye Sisson
- 2) Nitin Sampat
- 3) Bob Rose

Sources

¹Forus Health - 3nethra classic. (n.d.) *3nethra Classic* [Brochure]. Retrieved October 5, 2016, from <http://www.forushealth.com/new/3nethra-classic.html>

²Neuberger, B., Lanza, D., Rosengrant, N., Axel, P., & Olmsted, Z. (2016, October 5). *Design Review II* [PDF].

³VISUCAM PRO NM. (n.d.). Retrieved October 19, 2016, from <http://www.zeiss.com/meditec/us/products/ophthalmology-optometry/retina/diagnostics/fundus-imaging/visucam-pro-nm.html#technical-data>

⁴CenterVue. (n.d) *drs: Digital Retinopathy System* [Brochure]. (n.d.). CenterVue.

⁵Optomed. (2016). *Smartscope PRO Camera* [Brochure]. Retrieved October 5, 2016, from <http://www.optomed.com/blog/module/smartscope-pro-camera/>

⁶PanOptic™ Ophthalmoscope - Welch Allyn. (n.d.). Retrieved October 5, 2016, from <http://tinyurl.com/handheld-fundus-phone2016>

⁷Labourdette, K., Morency, I., Huynh, Q., Sui, D., Burden, K., & Casero, T. (2014, December 11). *Low-Cost Fundus Camera* [Scholarly project]. In *P15590: Low Cost Fundus Camera*. Retrieved October 18, 2016, from <http://edge.rit.edu/edge/P15590/public/Home>

⁸*Low-Cost Fundus Camera 2* [Scholarly project]. (2016, May 13). In *P16590: Low-Cost Fundus Camera 2*. Retrieved October 18, 2016, from edge.rit.edu/edge/P16590/public/Home