Detecting early stage pressure ulcer on dark skin using multi spectral imager

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ABSTRACT

This paper introduces a novel idea, innovative technology in building multi spectral imaging based device. The benefit from them is people can have low cost, handheld and standing alone device which makes acquire multi spectral images real time with just a snapshot. The paper for the first time publishes some images got from such prototyped miniaturized multi spectral imager.

1. INTRODUCTION

In the battle against epidemic diseases in medical and healthcare practice, such as various kinds of cancers, bed pressure ulcer and etc., searching for powerful, noninvasive engineering methodologies in multidisciplinary fields made bring multi spectral imaging technology to people's attention. This mature technology can always help people to effectively and efficiently detect, sort and further monitor target whatever the fields it is applied to [1]. Up to now, it is very hard to illustrate a field which did not use it yet. Also, the research in the past several decades made people have collected data, i.e. the innumerous sets of wavelengths which intrinsically character the targets people mostly wanted to discern in diverse applications, e.g. classification of difficult targets in defense, produce sorting, precision farming in agriculture, product quality online inspection in manufacturing, contamination detection in food industry, remote sensing in mining, atmospheric composition monitoring in environmental engineering, and early stage diagnosis of cancer and tumors.

The set of wavelengths are uniquely determined by the absorption of chromospheres for a given target. Just because of this feature, multi spectral imaging technology became right tool kit in detecting diseases in very early stage of evolution, i.e. something changed in the molecular level which is where people think diseases begins. This match makes application of the technology extendable to many biomedical research front areas, e.g. Quantum Dot in labeling protein in cancer study [2]. Recent food safety issues, e.g. inspection of contamination from virus is making and will make multi spectral imaging technology play much more important role than it has ever done.

Although multispectral imaging has matured into a technology with applications in many fields, clinicians and practitioners in these fields have generally stayed away from it due to extremely high costs and lack of portability. Also, current multispectral imaging applications require either multiple exposures or extensive post-processing. Examples of these current technologies include filter wheels, generalized Lyot filter, electrical tunable filter, optic-acoustic based SmartSpectra, NASA's Multi Spectral Imager. The cost of electrical tunable system: >40K with dimensions 6in x 6in x 6in and SmartSpectra: 60K with dimensions 9in x 9in x 9in.

With fund from NIH, a novel custom filter mosaic has been successfully designed and fabricated using lithography and vacuum multi layer film technologies by the imaging group of Center for Assistive Technology and Environmental Access, Georgia Institute of Technology. The filter incorporates four or more different wavelengths within the visual to near-infrared range each having a narrow bandwidth of 30nm or less up to application. The filter can be deposited on regular optical glass or directly on a CMOS and CCD imaging sensor (reference to a drawing in principle in Figure 1). This design permits multi-spectral images to be acquired in a single exposure. Only laminating this kind of filter on surface of CMOS or CCD sensor can people make change regularly industrial used monochromic camera to a multi spectral purposed camera without modifying any other part. Thereby, the novel idea and innovative technology

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introduced in this paper provide an overwhelming convenience in building multi spectral imaging technology based device, image acquisition and post image processing.

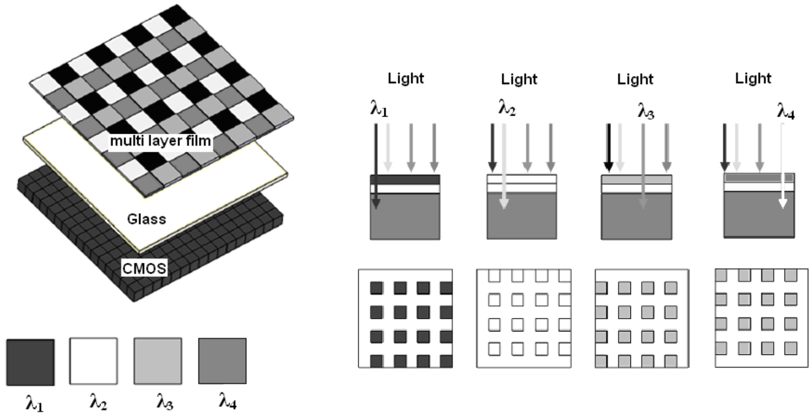
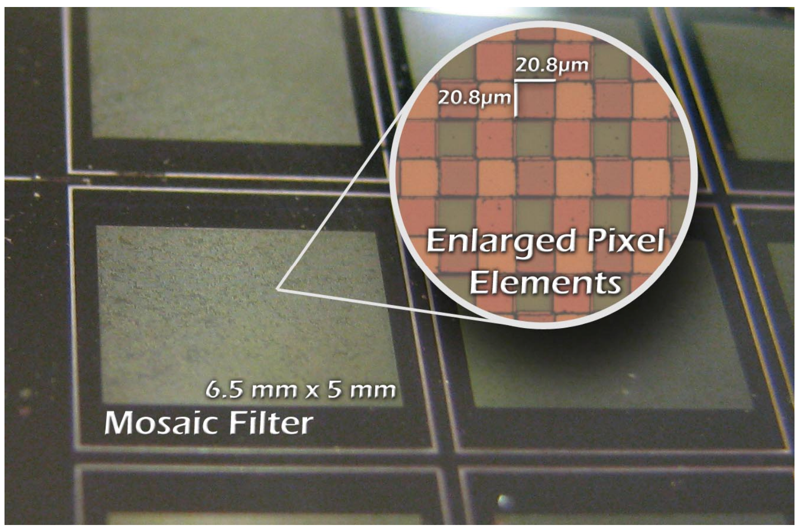
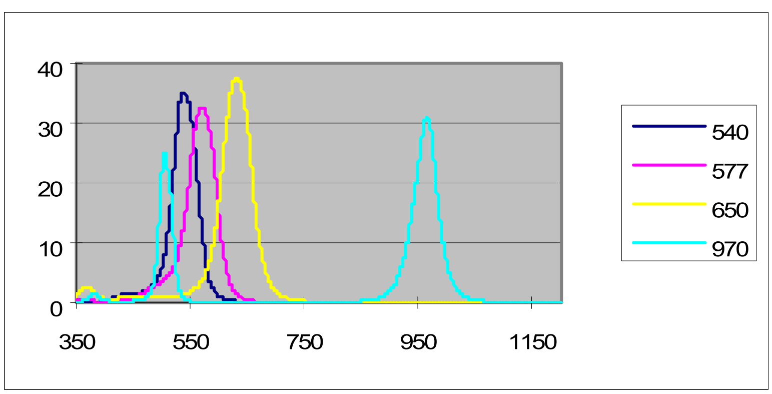


Figure 1. Four element color filter array as an illustration of mosaic filter



(a)



(b)

Figure 2. (a) A section of prototype mosaic filter for the set of wavelengths λ = 540nm, 577nm, 650nm, 970nm. The image shown was taken from CCD microscope. Subsequent improvements to the fabrication process have reduced the spacing

(gap, border) between individual filters to 1 µm - 2 µm. (b) Transmittance of a set of four featured wavelengths through the filter array

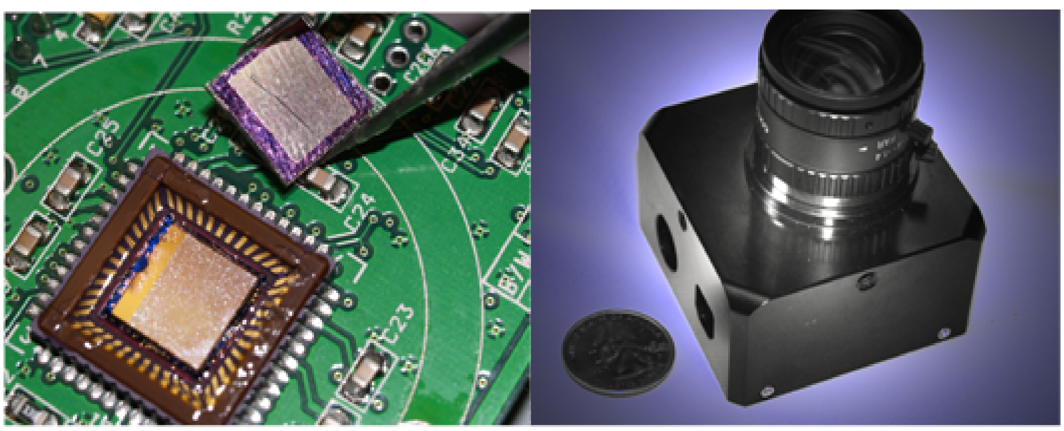
The primary commercial benefits of the new mosaic filter are cost and size. This technology can be used to create small handheld multispectral devices at affordable costs. The real-time imaging process permits the design of devices capable of working in the field or at the point of care.

Basically, the barriers to incorporate multi-spectral imaging in many industries have been cost and portability. This technology overcomes both barriers so applications in many fields is expected. For example, a clinician could easily find bruises on his or her patient by using a $300 handheld imaging device. Finally, because of its cost and simplicity, this technology may replace or supersede some multi spectral imaging technologies and devices currently marketed.

The filter array has been fabricated using wavelengths used in pressure ulcer and bruise detection. So, all the technical challenges of fabrication have been overcome.

2. A NOVEL MULTI SPECTRAL IMAGING TECHNOLOGY — TO TARGET HANDHELD, LOW COST, STANDING ALONE, REAL TIME AND CLINICALLY PRACTICALLY APPLICABLE DEVICE

The filter is then affixed to a CMOS sensor with a resolution of 1280 x 1024 and pixel size of 5.2 µm. It provides 320 x 256 pixels per this case and the 20.8 µm filter fits over 4 CMOS pixels. (a) and (b) in Figure 2 show a section of prototype mosaic filter for the set of wavelengths and their transmission wavelength profiles. Figure 3 shows a fabricated NBFM is going to be laminated with a CMOS sensor on board. Figure 3 is a prototyped miniaturized multi spectral imager (MMSI) and one illustrated snapshot result.



(a) (b)

Figure 3 (a) A filter mosaic (with the set of central wavelengths λ = 540, 577, 650 and 970nm) has been laminated with a CMOS sensor on a camera board (b) an assembled miniaturized imager for the purpose of detecting erythema.

The use of a custom filter array overlaying a CMOS sensor represents a novel idea to multi spectral imaging. The innovation provides simple, miniaturized (can be a cellular dimensions), low cost instrumentation (can be $300) that has many potential multi spectral imaging applications which require a handheld detector. Process of assembling miniaturized imager:

1. Lamination of filter mosaic onto CMOS sensor within digital camera

Mightex USB2 camera with monochromic CMOS sensor (MT9M001C12STM with one pixel dimensions as 5.2µx 5.2µ produced by Aptina Imaging) fabricated by Mightex is chosen as test bed to try the lamination craft. A defined new pixel on filter mosaic (with pixel dimensions as 20.8µx 20.8µ which covers four filters with central wavelengths 540, 577, 650 and 970nm) needs to precisely cover 16 original CMOS pixels. Figure 4 shows the computer controlled lamination setup. Tests showed that the maximum orientation mismatch and position misalignment between filter arrays and CMOS pixels can be controlled to be less than 1/1000 radians and 1 micron respectively.

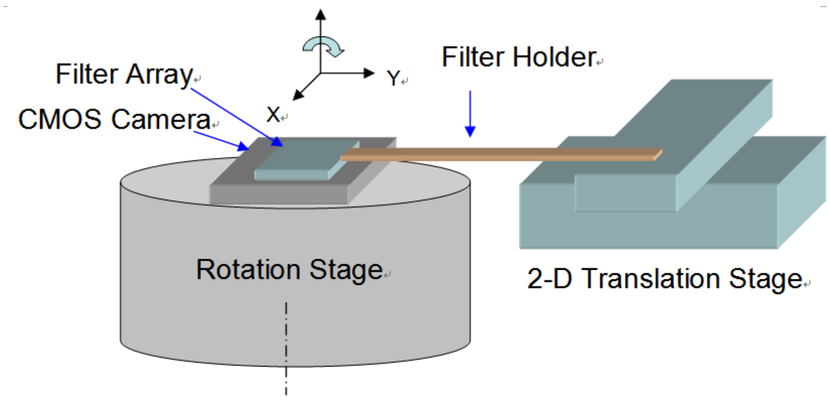
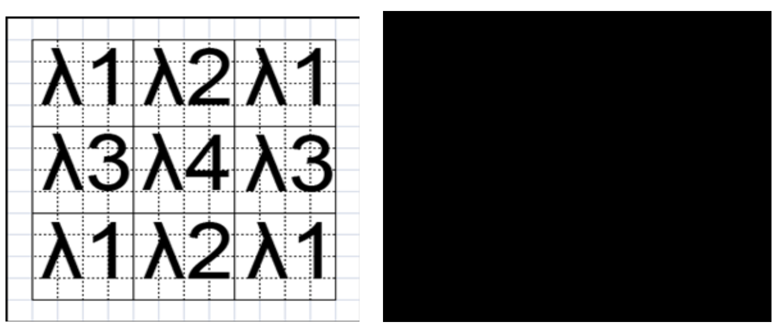


Figure 4 System schematic of active filter arrays alignment and lamination on CMOS camera

2. Configure camera to display multi-spectral images

The raw data from the camera are 1280x1024 monochrome bitmaps. Each pixel value is an 8 bit integer (0-255) representing the light intensity. Ideally, each filter unit (containing 4 wavelengths) will cover an area of 4 x 4 pixels (Figure 5 (a)). We use the mean value of each masked pixel area as a pixel in a new image. It means we will have 4 monochrome images with 320 x 256 defined new pixels. For the filter which has pin hold defect, hue of the new pixel is calculated by the average of the 4 neighbor pixels in the new image. Matlab based program is responsible for real time processing and showing images.



(a) (b)

Figure 1 (a) Defined new pixel has four narrow band filters expressed by their central wavelengths λ1 λ2 λ3 λ4. It covers 16 original pixels of a Aptina monochromic CMOS sensor. (b) Useful pixel region considering the existence of overlapping areas among the filters, the average hue value for each wavelength of a new pixel is calculated by using the area in red color as the indicated in (b)

3. Refine illumination system design and interface with camera prototype

A simple and low cost design is 3W warm white LED (produced by Luxeon and shown at

http://www.surplusgizmos.com/search.asp?keyword=luxeon&search=GO). Bench test showed that it is usable in acquiring multi spectral images. Figure 6 shows how a LED lighting system is installed and integrated with an imager

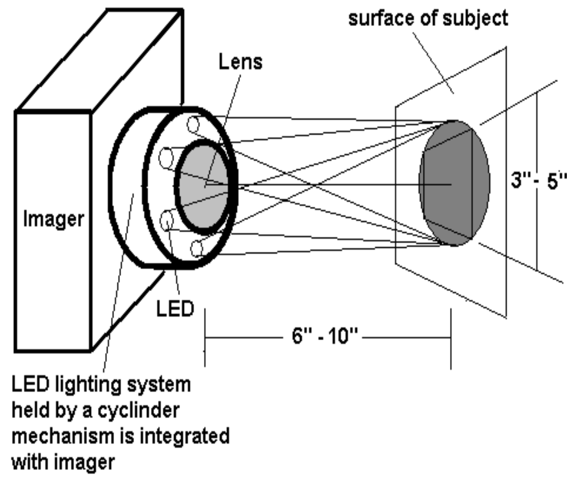


Figure 6 LED lighting system and integration with erythema imager

3. RESULTS

Figure 7 shows the images got from a snap shot of an arm with erythema induced on a dark skin. One snap shot makes get four images which correspond to four wavelengths. The fused image clearly shows the detected erythema (the round darker spot).

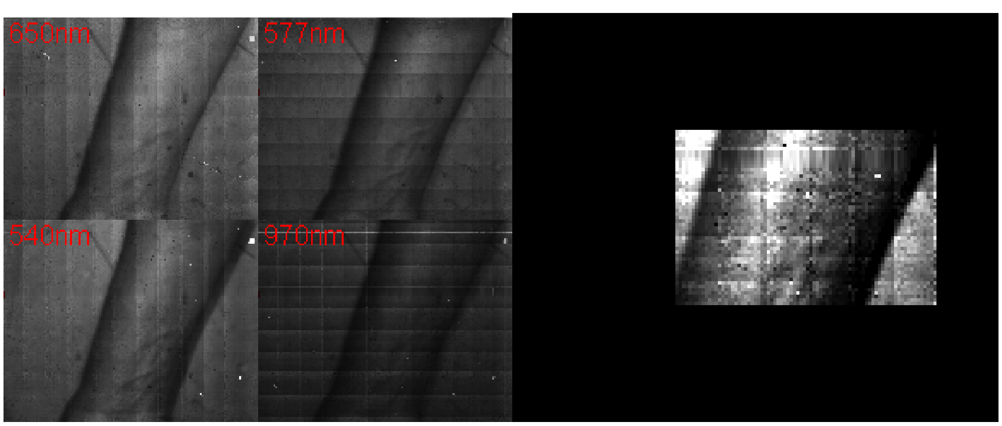


Figure 7 (a) real time acquired four images of an arm with induced erythema on the dark skin which correspond to four wavelengths 540, 577, 650 and 970nm (b) erythema area (a darker round spot) is detected and evidently shown by fusing the four images to enhance the contract between this area and other healthy skin area

4. CONCLUSION

We developed a prototype handheld diagnostic imaging tool capable of detecting erythema in individuals with darkly pigmented skin. The tool was developed by using a novel approach in assembling a multi spectral imaging device and a fabricated hardware component, i.e. Narrow Band Filter Mosaic (NBFM) [**Error! Reference source not found.Error! Reference source not found.**]. The innovative design of the key component makes the assembled device unique in that it is a handheld device as well as capable of being a 'stand alone device.' It is also a low cost, real time, multi spectral imaging system that significantly reduces post imaging processing time.

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