Computational Cellphone Microscopy

Aydin Arpa   Gordon Wetzstein   Douglas Lanman   Ramesh Raskar
MIT Media Lab

Figure 1: *(Left) Illustration of our cellphone microscope in the field. The data captured by this versatile and low-cost platform can either be analyzed directly on the phone or remotely, for instance by a medical doctor in a hospital. (Center) Our prototype consists of a standard cellphone camera, a secondary lens on a mount that is directly placed on the microscopic sample, and background illumination, for instance provided by an LED or a secondary cellphone display. Optical magnification is achieved by mounting a small lenslet at its focal length to the sample. (Right) Microscopic images showing stained apple cells, sea salt crystals, and onion cells.*

Abstract Within the last few years, cellphone subscriptions have widely spread and now cover even the remotest parts of the planet. Adequate access to healthcare, however, is not widely available, especially in developing countries. We propose a new approach to converting cellphones into low-cost scientific devices for microscopy. Cellphone microscopes have the potential to revolutionize health-related screening and analysis for a variety of applications, including blood and water tests. Our optical system is more flexible than previously proposed mobile microscopes and allows for wide field of view panoramic imaging, the acquisition of parallax, and coded background illumination, which optically enhances the contrast of transparent and refractive specimens.

Overview Today, an estimated six billion cellphone subscriptions exist worldwide with about 70% of those in developing countries (www.itu.int/ict/statistics). However, developing countries often suffer from a lack of access to adequate healthcare, which is party due to the cost and training associated with high-tech scientific instruments required for medical analysis. We present a low-cost portable microscope that uses a cellphone camera and a simple, secondary lens that is placed on top of the specimen. As illustrated in Figure 1, our device can be used in the field, for instance to analyze water sources for potential contamination, and can either directly process the captured data or transmit it wirelessly for remote processing. Cellphone microscopes provide a unique opportunity to make disease diagnosis and healthcare accessible to everyone, even in remote and undeveloped parts of the world.

Based on their optical setup, cellphone microscopes can be categorized into three methodologies: on-chip analysis, off-chip clip-on methodology, and on-lens approaches. The first category, "on-chip analysis", requires major, intrusive modifications to cellphone hardware [Tseng et al. 2010]. Furthermore, associated holographic imaging requires standard photographs to be reconstructed from captured fringe patterns. The second approach, "off-chip clip-on", requires additional hardware attachments to be mounted on the cellphone [Breslauer et al. 2009; Zhu et al. 2011]. Due to the varying dimensions of different cellphone models, however, a clip-on attachment usually only works with a specific model and also fixes the relative viewpoint of the specimen. The third methodology of cellphone microscopy can be described as an "on-lens" approach [Smith et al. 2011], where a refractive optical element is directly attached to the camera lens.

In this work, we introduce practical, low-cost, single lens off-chip computational microscopy using cellphone cameras. Our approach is unique in its optical design: a single lens is placed, separated by its focal length, on a microscopic sample and directly imaged from a detached camera phone, which allows different viewpoints of the sample to be recorded. We further demonstrate that an additional cell phone display can be used to provide structured background illumination, which optically enhances the contrast of the observed specimen. The focus of this paper is to make field microscopy practical and cost-effective at the same time.

Results and Discussion As seen in Figure 1 (right), we captured a variety of different microscopic specimens with our system. In contrast to other cellphone microscopes, our optical lens is not rigidly attached to the cellphone. Therefore, our approach facilitates wide field-of-view panoramas of microscopic samples to be captured (see supplemental video). We employ computational illumination, specifically a Schlieren imaging setup, in order to amplify the contrast of refractive transparent specimen. In summary, we have presented a new approach for low-cost cellphone-based microscopy. Our setup uniquely combines the characteristics of being cost-effective, non-intrusive, flexible, requiring minimal post-processing, and allowing computational illumination.

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