**Editorial**

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# Introduction to Blahnik and Schindelbeck's Smartphone Imaging Technology and its Applications

As a student studying optics, I worked several summers for a global film manufacturer based in Rochester, New York, USA. In my time there, I overheard some elevator conversations dismissing the rise of digital imaging. "Who would want a low-resolution digital image?," one person would say. Another would agree, adding "Yes, especially when you can't even make prints from them." At the time, reasonably affordable digital cameras required a frame grabber and computer to capture a modest $640 \times 480$ pixel image. Once obtained, there were no consumer-grade printers to adequately reproduce a color image. These criticisms failed to account for the rapid development of a variety of technologies that would coalesce to create the powerful and ubiquitous imager that is in nearly everyone's pocket. The resolution and reliability of digital sensors steadily marched to the point where they are no longer the limit of the camera performance and they can be stamped out by the millions. The optics have evolved to provide excellent performance with injection-molded plastics which have the advantage of rapid production and built-in alignment features compared to glass lenses. Prints have been replaced by digital displays exceeding the resolution capabilities of the human eye. The internet allows captured images to be shared worldwide in a matter of seconds. Wi-Fi and cloud computing has enabled even further increases in image storage, as well as near real-time image processing.

The concept of an image has evolved with technology. Photo albums of the past were filled with birthday celebrations, family vacations, and visits to grandparents. Photos not worthy of the photo album were relegated to shoe boxes stashed in the back of a closet. Today's digital cameras still capture not only these celebrations and explorations but also capture the more mundane. I photograph my grocery list. I use my smartphone camera to scan QR codes to get menus at restaurants and maps to parks. I use the camera to document serial numbers on pieces of equipment and repair or maintenance processes, so I can recall how to do these procedures in the future. Fortunately, I am not guilty of taking "selfies," but the practice has become all too common, enabled by the rear-facing camera on smartphones. Gone are the days of capturing 24 images on a roll of film, dropping it off for processing, and receiving prints back two weeks later. Gone are the days of pulling the prints out of the envelope, only to be disappointed that the flash did not fire, a finger was in front of the lens, or the scene was out of focus. Nowadays, I can take many pictures of a moment, hoping that one captures the essence of the scene. The other images are no longer relegated to shoe boxes, but instead, just become extra bytes on a computer or tossed out with a click of the delete button. Digital imaging has vastly expanded our ability to capture and remember the world around us, enabled by a multitude of technologies packaged into the slim confines of a smartphone.

Vladan Blahnik and Oliver Schindelbeck in their article *Smartphone Imaging Technology and its Applications* provide a comprehensive description of the evolution and design of smartphone camera systems. Included is a history of the evolution of the various smartphone imaging technologies, which provides a thorough overview for those of us who are too old to remember all the different technologies we have cycled through over the years, and for those of us who are too young to remember a time without smartphones with built-in cameras.

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Furthermore, detailed lens designs are examined, describing the tradeoffs in field of view, imaging performance, and compactness of the forward- and rear-looking cameras, as well as multi-camera systems. In addition to optical design, optomechanical aspects such as fabrication and mounting, as well as image quality enhancements such as autofocus and image stabilization are included. Finally, more advanced topics such as image processing, high dynamic range imaging, photogrammetry, portrait mode, and the simulation of effects such as Bokeh are covered as well. This article does not fit the traditional model of a journal article due to its length. In days gone by, this material would have been printed and compiled into a book for you to purchase or borrow from the library. Fortunately, the digital imaging revolution has also reached print media and this article can be provided to the readership at little or no cost. This enables Blahnik and Schindelbeck's work to reach a far broader audience and become the fundamental reference on smartphone imaging systems.