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The Future of Camera Technology with Atul Ingle

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Atul Ingle Podcast

Welcome to PDXPLORES, a Portland State University research podcast, featuring scholarship innovations and discoveries, pushing the boundaries of knowledge practice and what is possible for the benefit of our communities and the world.

My name is Atul Ingle. I am an Assistant Professor in the Department of Computer Science here at Portland State University. Broadly, my research is in the area of computer vision, computational imaging and signal processing. The big picture goal of my research is to design cameras that can capture images of phenomena that are otherwise difficult to capture with today's technology.

There are many limitations to today's digital camera sensors. One, they can only capture a limited range of brightness levels in a single shot. Another limitation is speed. Most conventional cameras have limited frame rates, maybe a hundred frames per second. If you pay a lot of money, maybe you get closer to 500 or a thousand frames per second. In some of my recent work, I have shown that a different type of camera sensor technology called single photon cameras can, in fact, be used to circumvent some of these limitations of conventional digital cameras.

So single photon cameras have the unique ability of capturing individual photons of light at extremely high speeds. Fortunately, there is this new rapidly developing single photon sensor technology called single photon avalanche diode SPAD for short, that has some promising features. It can operate in room temperature. It has extremely high sensitivity, and most importantly, it can be made very cheaply with high resolutions using the same fabrication technology that is being used today for manufacturing all kinds of electronics, including smartphone cameras.

Single photon camera technology can be used in almost all domains where conventional cameras are being used today. This includes consumer that. It could be augmented reality or virtual reality applications where you need precise 2D and 3D information about your scene. Many scientific imaging tasks also require high quality imagery, including say astronomy, microscopy, medical imaging. Single photon cameras will also be key enablers for autonomous robotics. Now this will include self-driving cars as one example. But there are many other application domains where autonomous and semi-autonomous robots are used.

Unfortunately, there is a challenge. This high sensitivity and high speed of SPAD cameras is a double-edged sword. Although they give you single photon information, they generate so much data, more data than conventional cameras, that right now we don't have good ways of dealing with that humongous amount of data. SPAD cameras have the potential to democratize single photon camera technology to the masses, but a challenge that needs to be solved for that to become a reality is to efficiently handle the large amount of data that these sensors generate.

The amount of data is so large that we can't just wait for the next USB-C connector to show up and hope that we will be able to handle this data. Those improvements in USB technology, let's say, or your Thunderbolt connector, those are incremental improvements of say a few percent every year or so, right, but so, for single photon cameras, these SPAD cameras. we need a paradigm shift in how we deal with this kind of data, because it's hundreds or thousands of times more data than what we can handle with today's technology.

We need a radically different approach to capture and process this new type of data that a SPAD camera generates. That is the primary objective of my project. I plan to tackle the data efficiency problem with SPAD cameras for two specific applications. One of them is passive imaging where you're just taking a 2D image of something, some object, just like regular photography. The second application is 3D imaging, where you are interested in capturing depth information, which tells you how far away is each point in your scene from the camera.

So, then the name of the game is to figure out if we can compress this information down, either by throwing some of the photons away or by applying some mathematical or statistical operations on this information. The question is which photons should you throw away and how do you apply, how do you figure out which mathematical operations to use to compress this data? It turns out there are many correlations in photon data that can be leveraged across space and time. Intuitively if one of your image pixels is bright, then it is very likely that one of the neighboring pixels is also bright. Similarly, if a certain point in your scene is let's say five feet away from the camera, then it's very likely that the points in its spatial neighborhood are also roughly five feet away from the camera. So, we will be designing algorithms that can exploit these types of correlations to design more efficient algorithms that don't need to store and transmit all of this photon data at extremely high speeds.

Eventually with even larger data sets. I also plan to train some deep neural network models, for example, that could compress this photon information on the fly, in real time. And perhaps one day, these algorithms will be implemented in hardware and they may even show up in a future model of your apple iPhone.

My name is Atul Ingle and I designed computer vision, hardware and algorithms that can capture structures and phenomena that are otherwise invisible to the human eyes.