In the past, it took a whole team of animators a few weeks just to craft a few seconds of compelling 3D computer graphics. With light field photography that allows the re-creation of an actual 3D space by a click of the shutter, this is about to change. Yet, this technology requires an array of micro-lenses, which is expensive to make, to produce slightly different images from different angles simultaneously. With the Compound Eye imaging system developed by the State Key Laboratory of Ultra-precision Machining Technology of PolyU, precise 3D images can be captured at a tiny fraction of the cost. Brace yourself for 3D photos and videos on every smartphone in the near future.

This may come as a shock to you – focussing before taking a photo will soon be a thing of the past. Light field photography changed the game completely by letting you choose your focal point, depth of field and perspective after you take the photo. Similarly, you can “direct” your cinematography after you shoot a footage. Panning, tilting, tracking and zooming can all be done afterwards. The core technology behind is an optical imaging module with an array of micro-lenses, which has been so expensive to produce that it only makes sense to put one in state-of-the-art equipment with a hefty price tag. Luckily, Prof. W. B. Lee, Chair Professor of the Department of Industrial and Systems Engineering cum Head of State Key Laboratory of Ultra-precision Machining Technology, and his research team developed the Compound Eye imaging system using a unique production method, costing only 1/10,000 as much as the conventional method. That would hugely democratize the making and reproduction of 3D images on portable devices.

Mapping 3D space in a split second
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To convincingly map a 3D space, tens of thousands of images of the same scene is captured from slightly different angles. Powerful software then analyses and calibrates the distances and spatial relationship between each and every object in the scene in order to re-create the actual 3D space. Instead of shooting thousands of photos one by one, we use a micro-lens array, or in this case the Compound Eye. “It is essentially tens of thousands of micro-lenses arranged in a grid, just like the complex eye structure of some insects with super sharp vision, hence the name. With Compound Eye, you just need to take one shot to acquire full 3D information about the scene,” explained Prof. Lee.

Ultra-precision machining and injection moulding

Each micro-lens is only 60 microns in diameter and 1 micron thick. As precision is needed to render them optically viable, micro-lens arrays have been made traditionally with complicated high-tech processes, such as photolithography, laser direct-writing lithography and ion etching, though some of them may still result in errors. All of these methods are expensive because they are done under stringently controlled conditions. The equipment for such processes can cost as much as HK$40 million. That explains why a traditional micro-lens array is priced at HK$5,000 each.

On the contrary, the Compound Eye fabricated by Prof. Lee and his team is made with injection-moulded optical resin so that the price can be as low as HK$0.5 per piece. “Injection moulding is the most common method of plastics manufacturing. The machines are not expensive and it only takes a few seconds to mould a piece. But the challenge is how to fabricate the mould insert. We have developed a novel method capable of machining thousands of lenslets in a small area of 1cm x 1cm. A single point diamond tool is used to cut the mould core and precision is kept within 100 to 200 nanometres. The product has excellent surface quality requiring no further polishing.”

Not only is the Compound Eye useful in recording 3D information, but also in reproducing 3D images. “A tablet or smartphone with a Compound Eye screen sticker can reproduce truly naked-eye 3D images. You don’t need to break the bank to make and watch 3D photos and videos in future.” said Prof. Lee. Apart from light field cameras, the Compound Eye can also be applied to devices where depth and distance information is essential, such as surveillance cameras, light field microscopes, 3D scanner drones and endoscopes.

In April 2016, the Compound Eye imaging system won a gold medal and a grand prize at the 44th International Exhibition of Inventions of Geneva, Switzerland.