Cameras and their Continuous Development

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Introduction

Film and photography are special art pieces that many confide in. Those who are in either of those fields have special devices that allow them to express their creativity in many ways. Those devices are cameras. These cameras are a very important piece of technology, especially with today's standards. The technology behind cameras is much more complex than people think. The thinking that goes behind each and every one that is produced is highly intricate. The development of digital cameras has been over a century's worth of hard work and dedication. As society progresses through yet another decade, there's more camera technology being developed every day. The technology behind cameras is a very important aspect of everyday life, and a lot of it has been used in different fields outside of the creative ones.

History/Background

The technologies that will be discussed are light-field photography, eye control autofocus, high-resolution far-field imaging, quanta burst photography, imaging of parafoveal cones, and continued use of streak cameras. The earliest instances of light-field photography date back all the way to the early 20th century, when physicist Gabriel Lippmann introduced the concept of integral photography. As time passed, several designs were proposed, but Lytro was perhaps one of the first companies to introduce light-field photography into the mainstream. Outside of commercial use, researchers believe light-field photography could be a valuable resource for medical and scientific use.

The first eye control autofocus was seen in its very early stages in the mid 1990s to early 2000s, when Canon popularized the concept with the EOS 5, EOS 50, and EOS 30 camera. In late 2021, Canon introduced the $6,000 EOS R3, which brought the eye control autofocus to the main stage. The EOS R3 is one of the first pioneers in successfully using eye control autofocus and what it means.

High resolution dates all the way back to the invention of the first cameras. The invention of the Kodak by George Eastman set the standard, and every camera that comes after it sets to achieve the goal of having a better picture. It is a very broad term that continues to this day. What was considered high resolution when the earliest cameras came out is now vastly different. High resolution would be considered 4K picture quality, or something along those lines.

Streak cameras have been around for over 3 decades. Developed in 1990 by Japanese company Hamamatsu Photonics K.K, these cameras provide millions of frames worth of photos for just a few seconds. Since their invention, they have helped researchers with so much information that cannot be seen by the naked eye. They continue to be used today.

Current Development / Technology and Industry

In the commercial side of cameras, countless innovations have been made. One such camera was the Lytro Illum, which was released back in 2014. The Illum was a very different piece of camera technology that wasn't seen at the time. According to David Pierce from The Verge, "Taking great photos with this camera has a different set of rules, a different guiding principle. Forget the rule of thirds; shoot for depth. Frame from below, because it makes everything look more dramatic. And most of all, stop half-pressing the damn shutter and expecting something to happen. Focusing doesn't matter anymore" (Pierce, 2014). The then listing price for the Illum was $1,499, packed a serious punch. It introduced a more broad approach to light-field photography. The truly neat thing with this technology is that photographers are able to focus their images after they take them. The Illum had one of the most versatile lenses as well, a microlens, which "extends from 30-250mm, and shoots everything at f/2 but later offers the ability to stop down as far as f/16" (Pierce, 2014). Unfortunately for Lytro, hardly anybody purchased the Illum, and the company ceased operations in 2018.

Another piece of light-field technology was just introduced last month in Korea. "A joint research team led by Professors Ki-Hun Jeong and Doheon Lee from the KAIST (The Korea Advanced Institute of Science and Technology) Department of Bio and Brain Engineering reported the development of a technique for facial expression detection by merging near-infrared light-field camera techniques with artificial intelligence (AI) technology" (*AI light-field camera reads 3D facial expressions*, 2022). This could introduce a wide array of new technologies. The article states that the technique has the options to reconstruct images in ways such as: refocusing, multi-views, and 3D image acquisition. However, several limitations with this technology exist, especially with the microlens being unable to provide accurate data. In order to combat these issues, the team "applied a vertical-cavity surface-emitting laser (VCSEL) in the near-IR range to stabilize the accuracy of 3D image reconstruction that previously depended on environmental light" (*AI light-field camera reads 3D facial expressions*, 2022). According to Professor Ki-Hun Jeong, the technology can be able to "analyze the facial expressions and emotions of humans" (*AI light-field camera reads 3D facial expressions,* 2022) This can be used for "mobile healthcare, field diagnosis, social cognition, and human-machine interactions" (*AI light-field camera reads 3D facial expressions*, 2022). It might take some time for this technology to become more apparent, but with the right funding from bigger companies, it could come to pass within a few years.

Another extremely unique piece of camera technology that has been recently introduced has been eye control autofocus with the Canon EOS R3. The meaning behind eye control autofocus practically explains itself. Photographers are able to look into the viewfinder, and whatever they look at automatically focuses. The EOS R3 has something the original eye control autofocus cameras did not: “Canon's original Eye Control AF system used just one light, but inside the Canon EOS R3's viewfinder there are eight LEDs, which emit different wavelengths of infrared light. Using a variety of light sources at different angles enables the system to function even if the user is wearing glasses or contact lenses. In addition, the detection system has much higher resolution than in the past – there's a 7,560-pixel scanner dedicated to acquiring Purkinje images of the eye.” (Nicholson, 2021). One very interesting aspect about the eye control autofocus on the EOS R3 has to do with the tracking. Instead of constantly following the eyes as they look around the frame, “Eye Control AF is designed to work in tandem with the Canon EOS R3's subject tracking, and it's used to select the subject to be tracked at the outset. Once that's been done, there's no need to stare at the subject – the camera takes control of tracking it and focusing as it moves” (Nicholson, 2021). Eye control autofocus is definitely here to stay. The one issue most would have with this camera is that it is incredibly expensive, priced at $5,999. However, like most developing technologies, it takes time for it to further develop and become more commercial. The prices of these cameras will most likely decrease, and Canon won’t be the only company to use eye control autofocus. It’s only a matter of time until more companies like Nikon and Sony utilize it more.

Now the technology that is being discussed from now on comes from a more technical research level. “In multi-view three-dimensional imaging, to capture the elemental images of distant objects, the use of a field-like lens that projects the reference plane onto the microlens array is necessary. In this case, the spatial resolution of reconstructed images is equal to the spatial density of microlenses in the array” (Navarro, H., Barreiro, J. C., Saavedra, G., Martínez-Corral, M., & Javidi, B., 2012). Inside this article, the researchers wished to prove that it's possible to increase the resolution of far-field imaging. Though this was in the early 2010s, the research done helped develop more advanced camera technology. After testing a few ways to improve the resolution, the researchers tested a "proof-of-principle" experiment: "A camera lens of f = 100 mm was used to conjugate the reference plane with the MLA. The MLA was composed by lenslets of focal length 0.222 mm arranged in square grid of pitch p = 0.930 mm (APO-Q-P222-F0.93 model from AMUS). A digital camera with a macro objective 1:1 was used to image the elemental images onto the sensor. To take the second snapshot we moved the MLA by means of micrometer actuators" (Navarro, H., Barreiro, J. C., Saavedra, G., Martínez-Corral, M., & Javidi, B., 2012). With this process, the technique "provides a method for increasing the final resolution of reconstructed images" (Navarro, H., Barreiro, J. C., Saavedra, G., Martínez-Corral, M., & Javidi, B., 2012), something a lot of cameras are able to do today.

Another piece of technology that was introduced in 2020 was Single-photon avalanche diodes, which has been helping the development of quanta burst photography. These SPADs "are an emerging sensor technology capable of detecting individual incident photons, and capturing their time-of-arrival with high timing precision" (Ma, S., Gupta, S., Ulku, A. C., Bruschini, C., Charbon, E., & Gupta, M., 2020). Single-photon cameras have been used with SPADs to develop quanta burst photography: "a computational photography technique that leverages SPCs as passive imaging devices for photography in challenging conditions, including ultra low-light and fast motion" (Ma, S., Gupta, S., Ulku, A. C., Bruschini, C., Charbon, E., & Gupta, M., 2020). Quanta burst photography could definitely become a good way to take photos, commercially and scientifically. There's a good chance it could prominently be used in sports photography to capture more of those moments in action.

Another interesting development of camera technology and its utilization is within the medical field. “The underlying pathophysiological processes that result in visual loss in diabetic retinopathy (DR) are yet to be completely understood” (Soliman, M. K., Sadiq, M. A., Agarwal, A., Sarwar, S., Hassan, M., Hanout, M., Graf, F., High, R., Do, D. V., Nguyen, Q. D., & Sepah, Y. J., 2016). In order to get a further understanding on the visual loss in DR, the researchers used an “rtx1 adaptive optics retinal flood-illumination camera. The imaging device is a noncontact en face imaging system that is composed of 3 main components: high resolution fundus camera, Shack-Hartmann wave-front sensor, and a deformable mirror, which permits real time correction of the aberration of the outgoing ocular wavefront. The camera uses an infrared illumination (wavelength of 850 nm) and has a resolution of approximately 2-[mu]m. The field of view is 4x4° that corresponds approximately to 1.2x1.2 mm square on the retinal surface based on the axial length of the eye” (Soliman, M. K., Sadiq, M. A., Agarwal, A., Sarwar, S., Hassan, M., Hanout, M., Graf, F., High, R., Do, D. V., Nguyen, Q. D., & Sepah, Y. J., 2016). The camera measures the patient's eyes at high speeds. These cameras provide doctors and scientists with more detailed information on how certain parts of the body work. Cameras like the rtx1 adaptive optics retinal flood-illumination camera will most likely be used for decades, unless an advanced form of the camera is created. It will without a doubt be seen in most medical facilities for the time being, especially for use with diabetes and visual loss. If they can help researchers like those listed above, then they’ll be staying around and may help discover new things about diabetes that have yet to be seen.

Cavitation creates air bubbles, and “the entire process from the laser-induced breakdown to the first collapse of the cavitation bubbles occurs in a space on the order of millimeter within a duration of the order of 100 microseconds, and the velocity of shock waves generated during the laser-induced breakdown and bubble collapse can reach several kilometers per second" (Han, D., Yuan, R., Jiang, X., Geng, S., Zhong, Q., Zhang, Y., Yao, Z., & Wang, F., 2021). Since the shock wave velocity is produced in nanoseconds, it is almost impossible to capture this on a regular camera. In the paper, the fastest device that was currently used at the time this was published was the streak camera, which "deflects the light over time in the direction perpendicular to a narrow slit where the light enters into the camera and the resulting image forms a streak of light. The most advanced streak camera can reach 7.00 × 1013 fps" (Han, D., Yuan, R., Jiang, X., Geng, S., Zhong, Q., Zhang, Y., Yao, Z., & Wang, F., 2021). In order to reach the nanosecond speeds that they need to help the camera capture the cavitations, the researchers used a PIV dual-head nanosecond pulse laser. "For the nanosecond exposure requirement, when the ambient light is blocked around the system, the industrial camera sensor can only receive light from the PIV dual-head nanosecond pulse laser. Hence, the exposure time of the image equals to the laser pulse width and it is reduced to 5 ns" (Han, D., Yuan, R., Jiang, X., Geng, S., Zhong, Q., Zhang, Y., Yao, Z., & Wang, F., 2021). With the help of the PIV dual-head nanosecond pulse laser, the streak cameras are able to capture the images the researchers need to investigate cavitations.

Conclusion

In conclusion, the technologies talked about in this paper have made a substantial impact on today's world. Light-field photography will most likely become more commercialized, but it all depends on what companies adopt the technology. It might not even happen, but if it doesn't, then it'll probably become a staple for researchers and doctors in all fields. The eye control autofocus will see more production through Canon, and possibly other photography companies. It's up in the air if the cameras that provide this technology will become cheaper. It could be, but it's not always certain. High-resolution far-field imaging will probably not be used too much, considering it's still being researched, but chances are that it won't be seen for a while. Quanta burst photography is also still in development. However, there is a very good chance that it will become commercialized in future cameras within the next decade or so. Considering it is just being introduced, time will tell when people will see this type of photography technology being used. Imaging of parafoveal cones isn't necessarily uncommon, but not too many people know about it. It will most likely be used for further diabetic research and other diseases. Lastly, the use of streak cameras will also not be super prominent, much like the imaging of parafoveal cones. However, it could be further developed and used for things such as astrological events like shooting stars, but that would probably take decades to come to pass.

The reason these technologies are so important is because it provides further explanation to a lot of research, but also these technologies could become increasingly more common in a world that continues to grow more advanced as the years go on. Some of this technology might become extinct, but that's all based on the future of society and what they choose to do with what they're given. They can make these technologies into something bigger, or ignore them and let them die. The choice is up to the future.

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