Bioinspired camera could help self-driving cars see better

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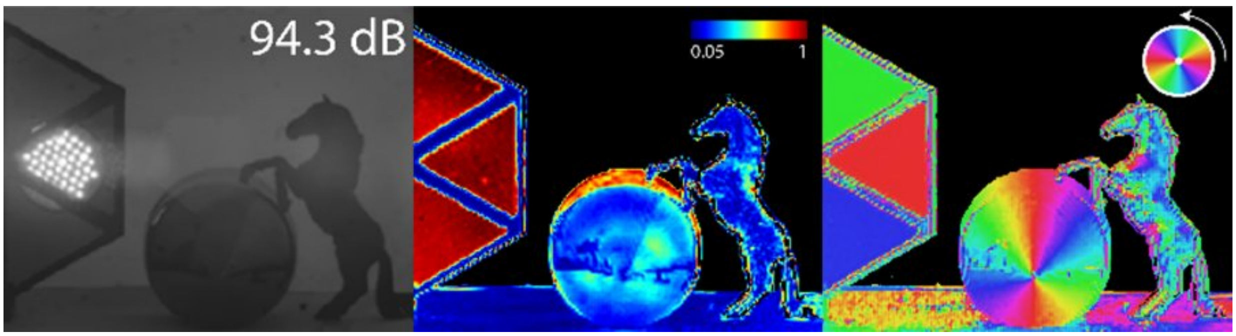

A new camera, inspired by the vision system of the mantis shrimp, features a dynamic range about 10,000 times higher than today's commercial cameras and can also image polarization information. The dynamic range and polarization capability can be seen in the light intensity image (left) and two polarization images (middle and right) acquired with the new camera. The scene imaged included a black plastic horse, an LED flashlight and a cone-shaped piece of silicon. Credit: Viktor Gruev, University of Illinois at Urbana-Champaign

Inspired by the visual system of the mantis shrimp—among the most complex found in nature—researchers have created a new type of camera that could greatly improve the ability of cars to spot hazards in challenging imaging conditions.

The new camera accomplishes this feat by detecting a property of light known as polarization and featuring a dynamic range about 10,000 times higher than today's commercial cameras. Dynamic range is a measure of the brightest and darkest areas a camera can capture simultaneously. With these, the camera can see better in driving conditions such as the transition from a dark tunnel into bright sunlight or during hazy or foggy conditions.

In *Optica*, The Optical Society's journal for high impact research, the researchers describe the new camera, which could be mass-produced for as little as $10 apiece. The researchers say the new camera would enable cars to detect hazards, other cars and people three times farther away than color cameras used on cars today.

"In a recent crash involving a self-driving car, the car failed to detect a semi-truck because its color and light intensity blended with that of the sky in the background," said research team leader Viktor Gruev of the University of Illinois at Urbana-Champaign, USA. "Our camera can solve this problem because its high dynamic range makes it easier to detect objects that are similar to the background and the polarization of a truck is different than that of the sky."

In addition to automotive applications, the researchers are exploring using the cameras to detect cancerous cells, which exhibit a different light polarization than normal tissue, and to improve ocean exploration.

"We are beginning to reach the limit of what traditional imaging sensors can accomplish," said Missael Garcia, first author of the paper. "Our new bioinspired camera shows that nature has a lot of interesting solutions that we can take advantage of for designing next-generation sensors."

Mimicking shrimp vision

Mantis shrimp, a grouping that includes hundreds of species worldwide, have a logarithmic response to light intensity. This makes the shrimp sensitive to a high range of light intensities, allowing them to perceive very dark and very bright elements within a single scene.

To achieve a similarly high dynamic range for their new camera, the researchers tweaked the way the camera's photodiodes convert light into an electrical current. Instead of operating the photodiodes in reverse bias mode—which is traditionally used for imaging—the researchers used forward bias mode. This changed the electrical current output from being linearly proportional to the light input to having a logarithmic response like the shrimp.

For the polarization sensitivity, the researchers mimicked the way that the mantis shrimp integrates polarized light detection into its photoreceptors by depositing nanomaterials directly onto the surface of the imaging chip that contained the forward biased photodiodes. "These nanomaterials essentially act as polarization filters at the pixel level to detect polarization in the same way that the mantis shrimp sees polarization," said Gruev.

Although traditional imaging sensor fabrication processes can be used to make the sensors, they are not optimized for making photodiodes that operate in a forward bias. To compensate, the researchers developed additional processing steps to clean up the images and to improve the signal to noise ratio.

Taking the camera on the road

After testing the camera under different light intensities, colors and polarization conditions in the lab, the researchers took the camera into the field to see how well it operated in shadows as well as in bright conditions. "We used the camera under different driving lighting conditions such as tunnels or foggy conditions," said Tyler Davis, a member of the research team. "The camera handled these challenging imaging conditions without any problems."

The researchers are now working with a company that manufactures air bags to see if the new camera's high dynamic range and polarization imaging capability can be used to better detect objects to either avert a collision or deploy the air bag a few milliseconds earlier than is currently possible.

Exploring the ocean

The researchers also received funding to use the new imaging system to make small GoPro-like cameras that could be used to explore the ocean. While GPS systems such as those in cell phones do not work under water, the new camera's polarization detection capability allows it to use the polarization of sunlight in water to calculate location coordinates. In addition, the camera's high dynamic range could be used to record high quality images under water.

"We are coming full circle by taking the camera, which was inspired by mantis shrimp, to different tropical oceans to learn more about how this shrimp behaves in its natural habitat," said Gruev. "They live in shallow waters and bury themselves under corals or in little burrow. This creates a challenging high dynamic range imaging situation because there's a lot of light in the water but dim conditions inside the holes."

More information: M. Garcia, T. Davis, S. Blair, N. Cui, V. Gruev, "Bioinspired polarization imager with high dynamic range," *Optica*, 5, 10, 1240-1246 (2018). DOI: 10.1364/OPTICA.5.001240

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