Calibration method improves scientific research performed with smartphone cameras

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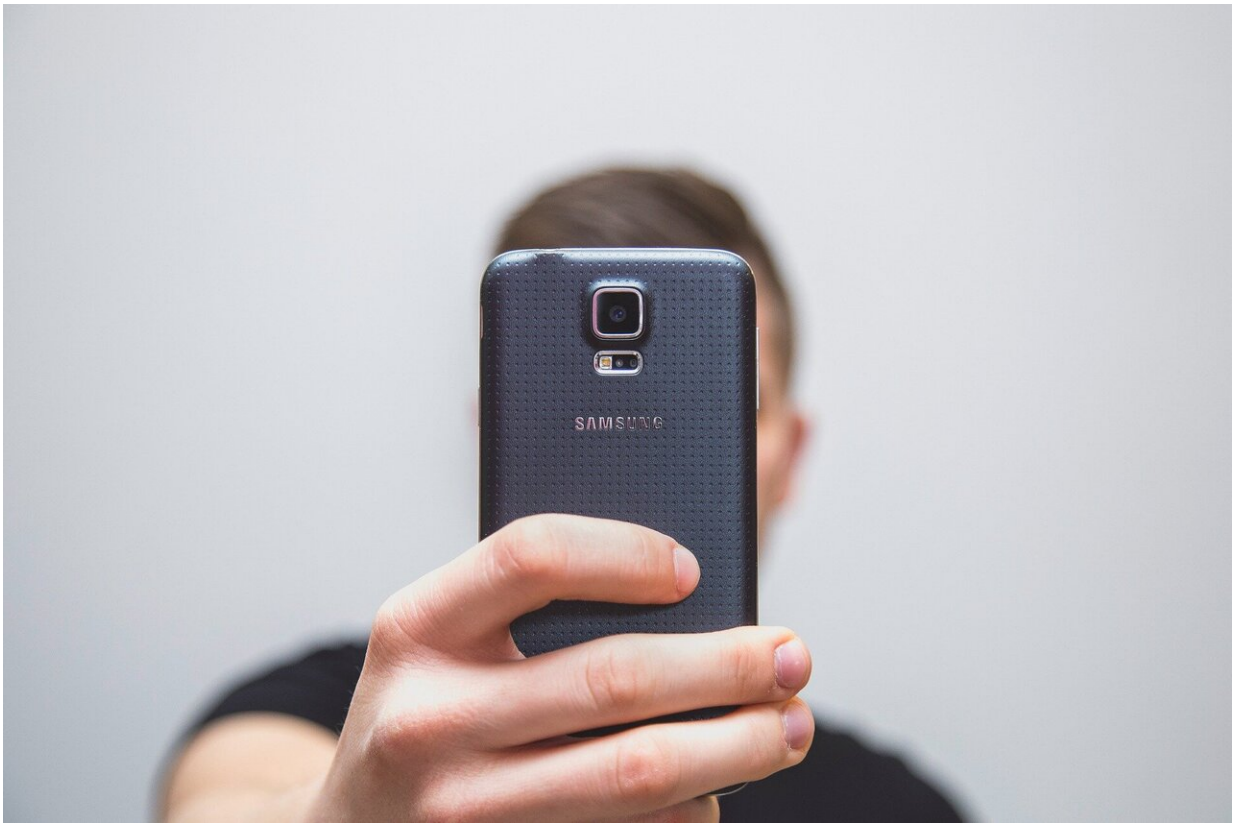

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Although smartphones and other consumer cameras are increasingly used for scientific applications, it's difficult to compare and combine

data from different devices. A new easy-to-use standardized method makes it possible for almost anyone to calibrate these cameras without any specialized equipment, helping amateurs, science students and professional scientists to acquire useful data with any consumer camera.

"The low cost of consumer cameras makes them ideal for projects involving large-scale deployment, autonomous monitoring or citizen science," said Olivier Burggraaff, who led the research team from Leiden University in the Netherlands who developed the calibration method. "Our standardized calibration method will make it easier for anyone to use a consumer camera to do things like measure pollution by detecting aerosol particles in the air."

In The Optical Society (OSA) journal *Optics Express*, the multi-institutional group of researchers report their new standardized calibration method and database, called SPECTACLE (Standardized Photographic Equipment Calibration Technique And CataLoguE), which can be used for smartphones, digital single-lens reflex cameras and cameras aboard drones. The database allows users to upload calibration data from their cameras for others to use.

"SPECTACLE includes many do-it-yourself (DIY) methods, which we found provided results comparable to professional methods that require high-end laboratory equipment," said Burggraaff.

Improving citizen science

The standardized calibration method was developed in response to a need that arose as Burggraaff and his Leiden Univ. colleagues were developing citizen science methods to measure optical water quality using a smartphone add-on called iSPEX (Spectropolarimeter for Planetary EXploration), they originally developed to measure air pollution. This add-on allows a smartphone camera to measure extra

optical information such as hyperspectral and polarimetric data. SPECTACLE and iSPEX are part of MONOCLE (Multiscale Observation Networks for Optical monitoring of Coastal waters, Lakes and Estuaries), a project funded by the European Commission aimed at creating sustainable solutions for measuring optical water quality.

"To use smartphone cameras to measure water quality we need to understand them well because each manufacturer and each device has its own characteristics," said Burggraaff. "SPECTACLE brings together many existing calibration methods and applies them for the first time to consumer cameras, which will make it much easier for other developers and for us to use these cameras for scientific purposes."

Although calibration methods for consumer cameras have been developed previously, these efforts were often hampered by a lack of access to the software or available information about the devices. For example, until recently it wasn't possible to access data straight from the camera sensor— known as so-called RAW data—or to control many camera settings like focus or exposure. However, new versions of iOS and Android allow both.

"As part of SPECTACLE, we are developing a framework for both operating systems to make measurements using RAW data and process these on the phone, which simply was not possible a few years ago," said Burggraaff.

DIY vs. laboratory methods

To test the new calibration methods, the researchers compared them with established methods using several cameras. They found, for example, that the DIY method for measuring how the lens distributes light on the sensor, known as flat fielding, matched within 5 percent of results from the standard method that requires an integrating sphere in a

laboratory setup. The DIY method involved taping paper on the camera and acquiring images of the sun or a computer screen.

They also tested the spectral response curves of a smartphone camera with the iSPEX attached and were able to achieve results within 4 percent of the professional measurement method, which requires an expensive and difficult-to-operate monochromator. The calibration of a single camera can take half a day with a monochromator, but the DIY method required simply taking a single picture of a piece of printer paper in the sun.

"We tested a number of cameras and found interesting differences and similarities between them," said Burggraaff. "For example, the cameras' responses to different wavelengths of light, known as spectral response curves, were very similar among most cameras except for a few devices that showed differences that could influence how the cameras sense and reproduce colors, even when imaging the exact same scene."

The researchers plan to apply the SPECTACLE methodology to a much larger number of cameras to fill in the database and get a broader idea of camera properties. This will be done by the researchers as well as anyone who wants to upload their calibration data into the database. They are also continuing to develop the iSPEX smartphone add-on to improve its ability to acquire water and air pollution measurements. This involves advancing its physical design and the algorithms for retrieving scientific results from its data while using the SPECTACLE methods and database to combine data from different smartphones.

More information: Olivier Burggraaff et al, Standardized spectral and radiometric calibration of consumer cameras, *Optics Express* (2019). DOI: 10.1364/OE.27.019075

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