December 2019

# Utilizing Spectral Sensor Data and Location Data to Determine the Lighting Conditions of a Scene

Jinglun Gao

Szepo Robert Hung

Gang Sun

# Utilizing Spectral Sensor Data and Location Data to Determine the Lighting Conditions of a Scene

**Abstract:**

This publication describes methods, implemented on an image-capturing device, to utilize spectral sensor data and location data to determine the lighting conditions of a scene. In aspects, an image capture manager implemented on the image-capturing device aggregates and fuses spectral sensor data and location data. A machine-learned (ML) model implemented on the image-capturing device analyzes the fused data and determines the lighting conditions of the scene. Using the determined lighting condition, a camera application implemented on the image-capture device adjusts camera settings (*e.g.*, white balance, exposure) to enable a user to take higher-quality photographs.

**Keywords:**

lighting conditions, lighting source, spectral sensor, location sensor, global positioning satellite system (GPS), Global Navigation Satellite System (GNSS), scene detection, photography, image capture, camera application, color spectrum, spectral power distribution, data fusion, machine learning, auto white balance, auto exposure

## Background:

Light, more specifically white light, is electromagnetic radiation across the visually perceptible portion of the electromagnetic spectrum. In other words, white light is a combination of visible light in the seven primary colors: red, orange, yellow, green, blue, indigo, and violet.

Different light sources, such as the sun, fluorescent light bulbs, light-emitting diodes (LEDs), and incandescent light bulbs, emit electromagnetic radiation of varying wavelengths and intensities. For example, the sun (natural daylight) emits light across the visible part of the spectrum, with a higher intensity in the blue light region of the spectrum. In contrast, an incandescent light bulb that utilizes a tungsten filament emits light across the visible portion of the spectrum with a higher intensity of red light in comparison to natural daylight. Likewise, sunlight on an overcast day is "cooler" (more blue in color), and full sunlight on a cloudless day is "warmer" (more orange/red in color when compared to the sunlight on an overcast day). These differences in light sources can impact the accuracy of color in a photograph taken by a camera. For example, a photograph of an object positioned outdoors in full sunlight will tend to be cooler than a photograph of the same object positioned indoors illuminated with an incandescent light bulb.

**Description:**

This publication describes methods implemented on an image capturing device (*e.g.*, digital camera, smartphone with image-capturing capabilities) for enabling the image-capturing device to measure spectral sensor data, measure location data, fuse the spectral sensor data and location data, and employ a machine-learned model that can analyze the fused data to determine the lighting conditions of a scene, such that camera settings can be adjusted appropriately.

An exemplary image-capturing device includes a display, processors, spectral sensors, location sensors, and a computer-readable medium (CRM). The spectral sensors generate spectral sensor data, including spectral power distribution (*e.g.*, measurements of the detected color spectrum, including wavelength and intensity (strength)) and light source frequency (*e.g.*, 60 MHz flicker), as well as changes in light illuminance (*e.g.*, brightness, luma strength). Spectral sensor data can be used by various camera algorithms, including those associated with auto white balance, lens shading, color shading, and auto exposure for banding/flicker cancellation. Utilizing the spectral power distribution and light source frequency, the luma strength, color spectrum, and AC/DC frequency (*e.g.*, 60 Hz) of the light source can be determined.

The location sensors (*e.g.*, global positioning satellite system (GPS) sensor, Global Navigation Satellite System (GNSS) sensor, Wi-Fi positioning system location sensor) generate geolocation sensor data that includes time and location information. The time and location information may include solar data (*e.g.*, sunrise, sunset, altitude, azimuth). Geolocation sensor data may be generalized sufficiently, such that no personally identifiable information can be determined, and yet useful data can be ascertained to determine, for example, time of day or environment (*e.g.*, inside a building).

The CRM may include the operating system of the image-capturing device, a camera application, and an image capture manager. Upon a user-initiated start-up of the camera application or in response to a detected scene change during the camera application runtime, the image capture manager can aggregate spectral sensor data from the spectral sensors and the geolocation sensor data from the location sensors together into fused data (*e.g.*, synced data of spectral sensors and location sensors).

In aspects, the CRM includes a machine-learned (ML) model. The ML model may be a standard neural-network-based model with corresponding layers required for processing input features like fixed-side vectors, text embeddings, or variable-length sequences. The ML model may be implemented as one or more of a support vector machine (SVM), a recurrent neural network (RNN), a convolutional neural network (CNN), a dense neural network (DNN), one or more heuristics, other machine-learning techniques, a combination thereof, and so forth.

The ML model may be iteratively trained, off-device, to analyze spectral sensor data and geolocation sensor data. The spectral sensor data and geolocation sensor data may be labeled with labels for different scenes that specify lighting sources (*e.g.*, sunlight, fluorescent light, LED light, incandescent light) and/or lighting environments (*e.g.*, dim lighting (low-light) environments, full sunlight environments, overcast environments, partly cloudy environments). During this training phase, the ML model can learn to associate spectral sensor data and geolocation sensor data with various lighting sources and/or lighting environments.

After sufficient training, the ML model can be deployed to the CRM of the image-capturing device. In use, the ML model takes synced (fused) spectral sensor data/geolocation sensor data and determines the lighting source/lighting environments for determining the lighting conditions of a scene, such that camera settings can be adjusted appropriately by the image-capturing device. For example, fused data may contain spectral sensor measurements of flickering light indicative of a fluorescent light source and location sensor measurements that indicate an indoor location. The ML model analyzes the fused data, determines that the lighting environment and light source are indicative of indoor artificial lighting and provides information to the image-capturing device (*e.g.*, a camera application on the image-capturing device), which can adjust camera settings appropriately for the determined scene.

Figure 1, below, illustrates the image capture manager and ML model jointly operating to determine lighting conditions.

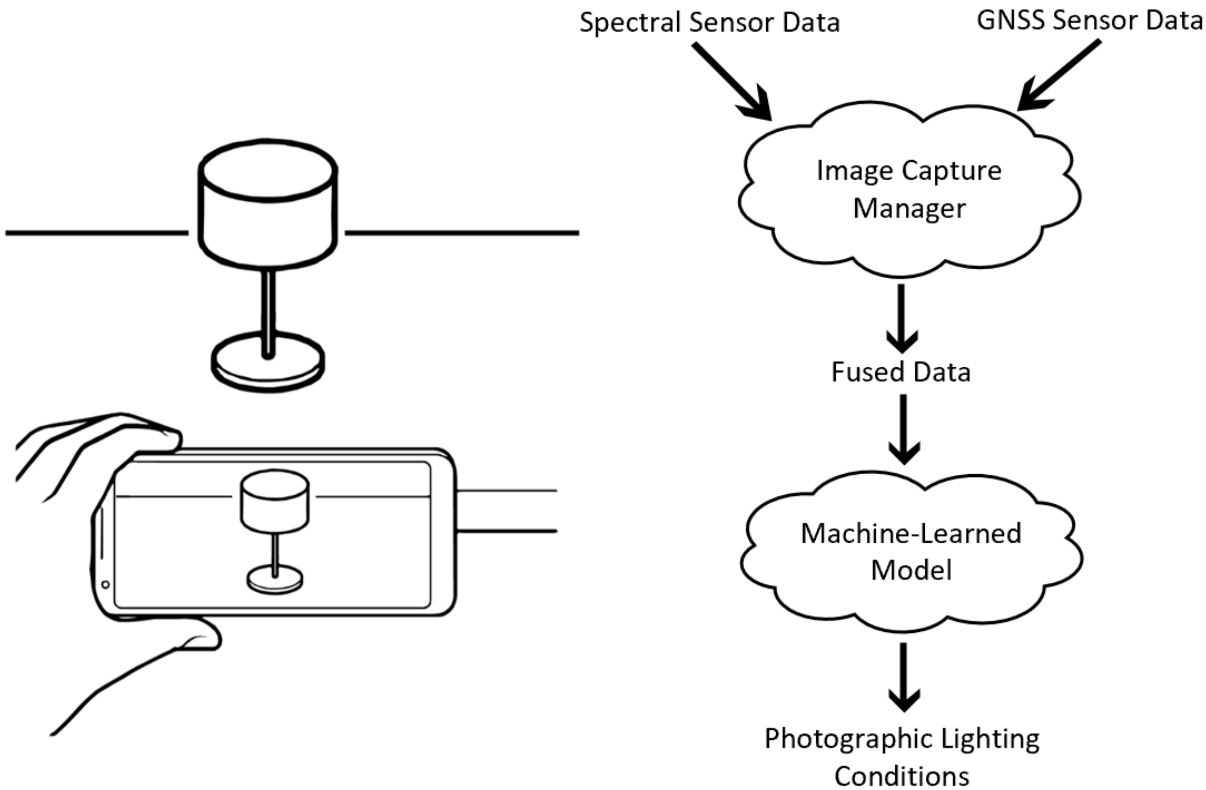


**Figure 1**

As illustrated, a user desires to capture a scene using his smartphone, so he loads a camera application on his smartphone. In the scene, the object of interest is a lamp, which is also the primary lighting source. Spectral sensors on the smartphone generate spectral sensor data, including spectral power distribution and light source frequency, indicative of an artificial light source, namely an incandescent light bulb. Simultaneously, location sensors on the smartphone generate geolocation data (*e.g.*, GNSS sensor data), indicative of a location within a building. Next, an image capture manager aggregates the spectral sensor data and the location data and fuses them together. Finally, an ML model analyzes the fused data and determines the lighting conditions for the scene (*e.g.*, determines that the lighting conditions for the scene are indicative of an artificial lighting source in an indoor environment).

With the photographic lighting conditions for the scene determined, camera settings can be initialized or adjusted appropriately. For instance, an incandescent light bulb, as the lamp in Figure 1 may utilize, emits light with the highest intensity in the red end of the visible spectrum. As a result, a camera, without proper adjustment, may capture an image that appears too dark and/or too orange/red. Therefore, if an ML model determines the lighting conditions are indicative of an artificial lighting source, such as the lamp of Figure 1, then camera settings (such as exposure and white balance), can be adjusted to capture an accurate image.

In another example, while hiking through the wilderness, Jane is using the camera application on her smartphone to capture images of birds. When she discovers a bird, she cautiously raises her smartphone, not wanting to frighten the bird. While Jane performs these actions, the image capture manager detects a scene change. As a result, sensor data from both the spectral sensor and geolocation sensor are aggregated and fused. The spectral sensor data may contain measurements that indicate a natural lighting environment (*e.g.*, light indicative of an overcast day). The geolocation sensor data may further indicate that Jane is outdoors. The fused data is passed to the ML model, and the lighting conditions are determined. The camera settings can be adjusted by the image-capturing device, using the lighting conditions, enabling Jane to capture a quality image of the bird.

In conclusion, the image capture manager operating cooperatively with the ML model to determine lighting conditions affords camera applications expedited settings configuration.

**References:**

[1] Patent Publication: US 20140275850 A1. GPS power conservation using environmental data. Priority Date: June 22, 2012.

[2] Benke, Darrell. "Improving Smartphone Cameras with Color Sensor Technology." *Embedded Computing Design*, November 10, 2016. https://www.embedded-computing.com/embedded-computing-design/improving-smartphone-cameras-with-color-sensor-technology.