Multi-application platform for education & training purposes in photonical measurement engineering & quality assurance with image processing

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Abstract. Involving children as well as students in photonical measurement engineering and quality assurance with image processing is becoming increasingly important due to the fact that children and students nowadays are well equipped with powerful mobile cameras and computers, for example smartphones. The Department of Quality Assurance and Industrial Image Processing at the Technische Universität Ilmenau noticed that standard measurement equipment within the labs does no longer encourage children as well as students to develop and apply conventional laboratory equipment for image processing. One reason could be that children and students are missing the playful approach to image processing technology and their applications which appears familiar to them from everyday life. To tackle this issue, within the above-mentioned Department a multi-application platform for education and training purposes on photonical measurement engineering and quality assurance with image processing has been developed. To adapt to the accepted player experience of young users a LEGO Train within a LEGO City environment has been introduced. Integrated within the multi-application platform, there are several image processing technologies like color webcam setup for 2D QR code readings, laser line and monochrome line-scan camera setup for 3D measurements, spectral filter equipped cameras for spectral image acquisitions and an infrared camera for thermal image acquisitions. Thereby children as well as students can experience image processing technologies in a playful environment. The paper shows HOW the multi-application platform has been constructed and HOW the applied image processing technologies have been implemented. The necessary hardware- and software setups can be practiced.

1. Introducing the multi-application platform
The development and application of photonical measurement engineering and quality assurance with image processing requires an interdisciplinary understanding of illumination, optics, sensors, interfaces and image processing algorithms. The application of image processing is manifold and is practiced in industry, biology and medicine. To show a part of the broad spectra of applications to children and
students the multi-application platform was engineered. The multi-application platform shows a LEGO Train within a LEGO City environment (Figure 1).

The LEGO Train was mechanically and electronically improved with a Bluetooth wireless communication module and a stepper motor as well as a 3D printed housing for the implementation of the stepper motor. The rail bed of the LEGO “Railway Station” was equipped with two inductive sensors which interact when the LEGO Train passes. Furthermore, there are different LED illuminations and a designed “landscape” to improve visually the LEGO City environment. Within the application-platform a micro-controller board has been implemented for communication and control of the LEGO Train and the LEGO City environment. The firmware of the microcontroller board was written in standard C language and enables the communication and control of the LEGO Train and the LEGO City environment by a standard Windows based computer and the MATLAB programming software via standard COM-Port commands. With MATLAB, an intuitive touchscreen operable software was written. With this software, the LEGO Train and the LEGO City environment can be controlled.

The implemented image processing can be accessed via USB and GigE interfaces. The MATLAB software processes and visualizes the acquired signals. Further information of the realized applications will be discussed in detail in the following sections.

![Figure 1](image.png)

**Figure 1.** Multi-application platform with image processing

(a) color webcam setup for 2D QR code readings,
(b) laser line and monochrome line-scan camera setup for 3D profile measurements,
(c) spectral filter equipped camera for spectral image acquisitions and an
(d) infrared camera for thermal image acquisitions.

2. Developed and applied color webcam setup for 2D QR code readings
To tackle a standard 2D image processing task which is known by young children as well as students from real life and daily applications a module for 2D QR code readings was realized and applied. For the image acquisition a standard color webcam was equipped with a diffuse LED ring light (Figure 2, left). When the LEGO Train stops at the LEGO Railway Station the LED ring light at the first LEGO Train Wagon illuminates the measurement scene and the color webcam is acquiring an image. The acquired image is processed within the written MATLAB software in a try, catch - execute statement and catch resulting.
The function for finding and decoding the QR code (Figure 2, center) within the acquired image locates the QR code embedded in the image and extract the string message embedded within the QR code (Figure 2, right). The used function to locate and decode the QR code works with added entries to dynamic Java class path in the open available Google zxing library [1]. For deeper insights, the MATLAB source code of the multi-application platform is open available on GitHub [2].

Figure 2. Color webcam with surrounded LED illumination (a), QR code example (b) and QR code decoding result (c).

3. Developed and applied laser line illumination and monochrome line-scan camera setup for 3D measurements

Laser triangulation, with its general low cost and simple implementation, is nowadays a widespread technology. The possible applications span from biomedical to industrial applications [3]. From a basic point of view, a laser-triangulation system consists a laser source with a lens that focalizes or collimates the laser beam on the target. A CMOS sensor camera and its optical system are used to acquire the laser line image on the target. The laser line is directed to the surface of the object at an oblique angle (Figure 3) [4]. It creates a visible line on the object. In areas where the object is lower, the beam is slightly shifted. By means of a camera this displacement of the bright laser lines can be determined in the image [4].

Figure 3. Basic principle of applied laser triangulation [4].

If the angle between camera and laser and the displacement of the line is known, the height of the object can be calculated by simple trigonometric formulae (right-angled triangle) (Figure 4) [4].
Figure 4. Calculation of the height of the object by using a simple trigonometric formula [4].

If the laser line runs on the object at a shallow angle, even smallest differences in height cause a strong displacement of the lines, however, the detected height range is low. Even differences of tenths of millimeters can be detected easily in practice without special effort. In case of obtuse angles, the measuring accuracy is low, but large differences in height can be detected. The principle of laser triangulation is brought to perfection when using 3D triangulation cameras and lasers. For this purpose, the test object is continuously moved along a camera-laser system and many triangulation profiles are generated. From the deflection of the single line profiles, a three-dimensional image of the object can be calculated using complex software algorithms [4].

For the realized 3D measurement setup, a self-developed laser line module and a camera both with 3D printed housings (Figure 5, left) have been used. The measurement object is a miniaturized toy car (Figure 5, center). During a special round of the LEGO Train - especially for the 3D laser line profile acquisition - the LEGO Train strongly decreases its driving speed. That allows the acquisition of more than 350 images within a measurement range of about 10 centimeters with the line based monochrome camera. That allows the 3D reconstruction of the 3D surface of the measurement object (Figure 5, right).

Figure 5. Laser and camera for applied 3D measurements (a), the measurement object (b) and the calculated three-dimensional image of the object (c).

4. Developed and applied spectral filter equipped camera for spectral image acquisitions

For the demonstration to children and students a spectral camera system was implemented into the application-platform to see things which are invisible for the unarmed human eyes. A monochrome CMOS camera equipped with a spectral bandpass filter at a center wavelength of 650 nm and a 50 nm Full-Width-Half-Maximum (FWHM) between the camera objective and the sensor (Figure 6, left). The application example is a 10 EUR bank note (Figure 6, center).

When the LEGO Train stops at the LEGO Railway Station a broadband halogen illumination turns on and within the image of the spectral filter equipped camera one special security property of the bank note becomes visible and is shown on the screen by the MATLAB software (Figure 6, right).
5. Developed and applied infrared camera for thermal image acquisitions

Another technology of image processing is the so-called thermal imaging with an uncooled longwave-infrared camera. It uses a sensor that works by the changes of voltages when heated by infrared radiation. These changes of voltages are then measured and compared to the values at the operating temperatures of the sensor. The higher an object's temperature, the more infrared radiation is emitted as black-body radiation. A special camera can detect this radiation in a way like an ordinary camera which detects visible light. It works even in total darkness because ambient light level does not matter. This makes it useful for rescue operations in smoke-filled buildings and underground. Furthermore, some physiological activities, particularly responses such as fever, in human beings and other warm-blooded animals can also be monitored.

The thermal imaging setup is used to show and explain children as well as students the huge variety of spectral intensity distributions in wavelength ranges from 5.000 nm up to 15.000 nm. The thermal camera can also be applied for relative temperature measurements of people who stand in front of the multi-application platform. It can be demonstrated that with image processing acquired quantities can be transferred into usable and comparable SI unit’s equivalents.

6. Summary and Conclusions

It has been shown that photonical measurement engineering and quality assurance with image processing for education and training purposes can be demonstrated by applications with a LEGO Train, a LEGO City environment, LED illuminations, cameras for visible and infrared light, appropriate filters and specialized software for micro-computers with WINDOWS operating systems. In the Department of Quality Assurance and Industrial Image Processing at the Technische Universität Ilmenau the Multi-Application Platform (MAP) is used for education and training purposes in the before mentioned image processing application fields.

References
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