Enhanced face ID security uses 3D TOF camera

Modern comprehensive face recognition systems are using the advantages of 3D TOF camera systems. They help make security systems more secure, especially against attempts at fooling the system by replaying 2D videos instead of presenting the real face.

Keywords: Face recognition, Time-Of-Flight, TOF camera, 3D camera, Security system

Summary

Today's modern 3D Time-Of-Flight (TOF) camera technology enables manufacturers of security and locking access or identification systems to build secure 3D facial scanning systems.

Shown here is the basic principle of how such an identification camera has to be built based on ESPROS' time-of-flight technology.

Introduction

Was this the vision which the Brothers Grimm tell us about in the story of “Snow White”: «Mirror, mirror on the wall, who is the fairest one of all?»

Not at the time of the writing of the story nor some years ago like in the 1980s, did anyone imagine how fast this proverb would become reality. Today in 2018, girls and boys are smiling into their mobile phones and thinking: «Mobile, mobile in my hand, unlock the screen to the fairest one of all».

This “romantic function” is called by engineers in dry and simple words: Face identification. It is a major key technology of this century - even truly in the real meaning of unlock and lock. Mechanical keys, electronic keys, pin codes, retina or fingerprint identification, and now face recognition: This is the consequent intention of the engineers to handle identification and security functions more and more unobtrusively.

Whereas, the development was started on the basis of conventional 2D pictures, the security aspects more and more became the center of this application. It means finding the dominating features in a picture which can identify a face as unique.

But our face has more than two dimensions - there is one more. This is the big opportunity for the upcoming new 3D imager technology to give this application an entirely new parameter, the depth, to make it much, much stronger.

Key factor security

Traditionally facial recognition data are acquired with 2D imagers. This way, you get at minimum a 2D black & white or color picture. If you need additional 3D data, the person, which need to be identified, has to turn its head. Out of this data, modern algorithms can extract 3D data as an additional observing and identifying parameter. The algorithm can usually identify too if it sees a mask or a living face. The problem starts if this identifier camera looks to screens which display videos with exactly this “3D” data information. In such cases, the locking system cannot distinguish between a fake and the reality. By the way, even if a stereo cam system is used, the same trick can be applied due to the fact that the presented data has to be available only in a 2D data format for each camera.

This is exactly the point of strength and the most important benefit for additional security by using a true 3D TOF camera:

- It requires received imaging data that is synchronized to the illuminating system.
- The data needs to match the systems dynamic.
- It needs a true 3D model reflecting the modulated light.
- Due to run-time acquisition, the security algorithm can check if the 3D model is a static mask or a living person based on the time-domain data.
- Such systems also offer the possibility to change the illumination modulation-frequency or illumination sources and intensities on the fly, making external synchronization of fake data nearby impossible.

To fake such a dataset becomes quite hard!

Key factors for mobile applications

A good choice to do this is by using ESPROS' epc660 3D TOF imager chip. The USPs of the chip - high sensitivity as well as the capability of suppressing strong ambient-light - make it in a favorite choice for mobile applications.

High sensitivity means saving battery power and allows eye-safe operation due to fact that the active illumination can be designed to be less powerful.

Ambient-light acceptance is a key factor and a challenge for devices although they are used outdoor in a full sunlight environment.

The system concept

The ESPROS epc660 evaluation kit includes a demonstrator for such an application and supports the implementation thereof into real devices. A picture is shown in Figure 1 which can also be seen live in a video on our website www.espros.com.

Figure 1: 3D facial scanning with epc660

The 3D image shown is live! The key ingredients to this stunning performance are an epc660 chip with a modulation frequency of 36 MHz, VCSEL illumination, a good camera calibration, and some relatively simple software.

Short summary of the result is:

- Simultaneous acquisition of true 3D TOF and self-illuminated grayscale images.
- Distance resolution 0.13mm.
- 5 security-key images per second with a 1GHz ARM8 processor.

Calibration by using on-chip DLL

3D TOF camera calibration and compensation is essential for obtaining the best image quality. It is therefore common practice. Several calibration parameters are stored in the camera for each individual pixel (such as dark signal offset and gain and color correction). Time-of-Flight image sensors need a good calibration setting as the calculated object distance is sensitive to signal delays in the order of ten to one hundred pico-seconds (equivalent to 1.5mm to 1.5cm distance change). This cannot be avoided in the design of the TOF pixel array because wiring length differences between different parts of the pixel array exist which causes different delays within this order of magnitude. Distance errors also occur by a few degree temperature differences as electron mobility in silicon is highly temperature dependent. Therefore calibration and compensation are key for high performance TOF sensors.

ESPROS uses their unique on-chip delay line DLL integrated on the TOF image sensors (such as the epc660 imager with 320x240 pixel field used here) and an proper procedure to calibrate the camera. The procedure does not require moving targets on a linear stage as is commonly used. A small, fully passive benchtop box is entirely sufficient for the calibration. This saves enormous cost and time during camera production.

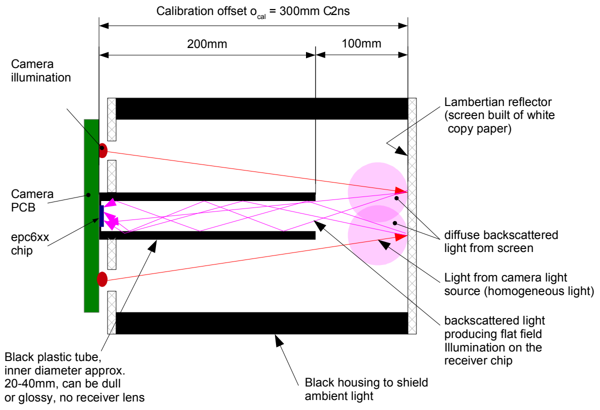

Figure 2: Proposed calibration box with camera (green)

A simple 30cm long calibration box according to Figure 2 is used. It allows docking of the camera (lens removed!) to the front of the box. The box contains holes for the camera illumination sources.

The purpose of the box is to shield the camera from ambient-light and to provide an optical reference plane in front of the sensor. It is a simple way to create a flat-field illumination for the imager which is very important for a high quality calibration.

The LED output of ESPROS' 3D TOF chips can intentionally be delayed step-by-step by the DLL in order to add a phase shift between the modulation and the demodulation of the light signal. Such a delay in the modulation path is equivalent to a distance shift of the object.

The distance response non-uniformity (DRNU) errors in general vary pixel by pixel. Additionally, they also vary as a function of the phase angle which represents the distance of the object to the camera.

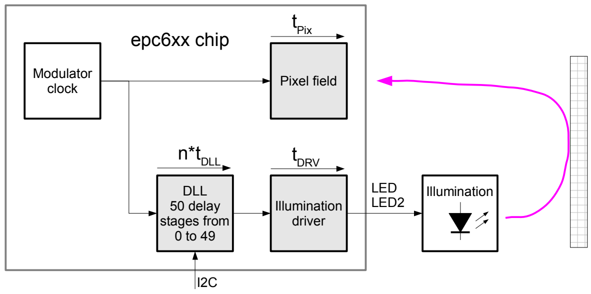

Figure 3: The DLL stages in the modulation/demodulation path

All pixels need to be compensated individually based on calibration data. ESPROS' simple way: By using the box and the corresponding DLL stages, the necessary number of calibration images can be acquired and stored pixelwise over the needed measurement distance range.

Runtime compensation

During runtime, full distance compensation is achieved by using DRNU correction and applying the following procedure:

Step #1
Execute common intensity compensation (offset and gain)

Step #2
Calculate the raw distance based on the values of step 1

Step #3
Calculate compensated distance by applying DRNU correction

Step #4
Compensate temperature drift

Step #5
Calculate the final absolute distance result with zero offset compensation.

Processing has to be done pixel by pixel.

A more detailed description of this principle for calibration by individual DLL steps can be found in ESPROS' Application Note AN10. Seethe Downloads section on www.espros.com .

The essence of image processing

Even with a well designed and calibrated camera, the task is not finally done. The raw data output from the camera, the point cloud, needs additional image processing to achieve the most reliable results. Usually, it is done by spatial filtering in the image domain (e.g. Median or

Gauss filters) and temporal filtering in the time domain (e.g. adaptive Kalman filters). The following pictures show the before and after.

Figure 4: Raw data point cloud

Figure 5: Final face ID image

Results and conclusion

ESPROS demonstrates with a modified DME660 camera the way to successfully design a 3D TOF security camera for facial recognition which can even be realized and integrated in a mobile device like mobile phones, tablets, etc. - see Figure 6.

Figure 6: Example of a customer 3D TOF camera for mobile applications using the epc660 chip

A full pixel-field and fast camera calibration is necessary and of high practical importance.

With the proposed concept however, the calibration can be done in a small box within a few minutes without moving parts. Hundreds of cameras can be calibrated in parallel with a very low investment.

Such security cameras can be designed with the ESPROS TOF chips epc635 and epc660.

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