2D+3D Face Imaging for Stand-off Biometric Identification

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Abstract: We developed and tested a Fourier Transform Profilometry, 2D+3D face imager operating with subjects moving at ≤1.5 m/s at ≤25-m range with <1.4-mm resolution and range precision at 1-Hz capture rate using low cost components.

OCIS codes: (150.6910) Three-dimensional sensing; (110.6880) Three-dimensional image acquisition; (120.2650) Fringe

1. Introduction

The ability to capture biometric data from minimally cooperative subjects with a minimally invasive system at significant stand-off distances is desired for security and defense applications. Lockheed Martin Coherent Technologies has developed a Fourier Transform Profilometry (FTP) based 2D+3D face imager operating with minimally- to non-cooperative subjects moving at ≤1.5 m/s at ≤25-m range with <1.4-mm lateral resolution (at maximum range) and <1-mm range precision at 1-Hz capture rate using technologies that are potentially low cost in production. Studies have shown that 2D+3D multi-modal face recognition performs better than either 2D or 3D face recognition alone. We, therefore, designed our system to capture 2D grayscale and 3D face imagery simultaneously with a single camera so that the 2D and 3D data are inherently pixel registered. In order to operate with minimally- to non-cooperative subjects, our system includes person and head/face acquisition and tracking with automatic focusing. The transmitter is Class 1M eye-safe as measured in accordance with the ANSI Z136.1 (2007) standard.

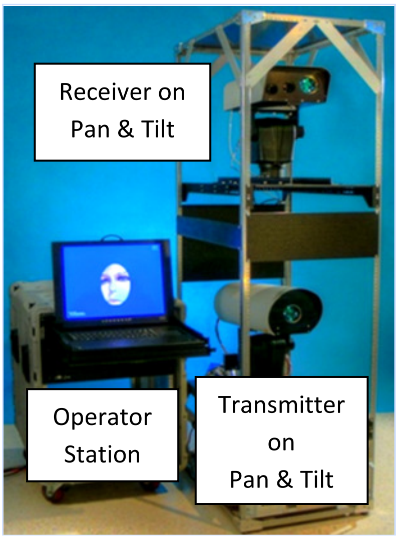
2. Fourier Transform Profilometry (FTP) Technique

The method of 3D shape measurement called Fourier transform profilometry (FTP) was invented by M. Takeda, et. al., in 1982 [1]. FTP is based on projecting an intensity fringe pattern onto an object and imaging with a camera offset laterally from the fringe projector. The FTP processing consists of computing the two-dimensional Fourier transform of the fringe image data, extracting the complex data in the spatial frequency domain near the fringe carrier spatial frequency (bandpass filtering), inverse Fourier transforming the filtered data to form a complex spatial image, extracting the "wrapped" phase image from the complex image, "unwrapping" the "wrapped phase," and scaling the "unwrapped" phase image to spatial dimensions.

3. 2D+3D Face Imager Engineering Development Unit (EDU) Description and Test Results

Figure 1 shows a photograph of the 2D+3D Face Imager Engineering Development Unit (EDU). The EDU uses a Class 1M eye-safe pulsed near-infrared diode laser transmitter at 1 Hz pulse rate in order to produce sufficiently short pulses with sufficient peak power to reduce image smearing to sub-millimeter levels for brisk walking speed motion (≤1.5 m/s). By operating in the response band of silicon detectors, inexpensive CCD/CMOS digital video cameras can be used. A wide field-of-view camera is placed on top of the EDU rack to capture video images for person tracking by software developed by GE Global Research. In our current EDU, the 2D and 3D face recognition ID matching is performed using the FaceVACS-SDK commercial software from Cognitec Systems Corporation.

We used the EDU to collect data on people at brisk walking speed (~1.5 m/s) at standoff distances from 10 m to 30 m. Most of the data were collected at 10-m standoff distance due to the available space limitations for collecting data on a group of 40 volunteers, but we also took data on a few individuals at standoff distances up to 30 m. This latter data showed that the EDU was limited to standoff distances up to and including 25 m as configured for these tests. Measurements on calibration targets confirmed that the EDU met the goals of pixel-limited lateral resolution (1.3 mm at 25 m) and <1 mm range precision. Figure 2 shows the results for matching one of the subjects' gallery image against her undisguised and disguised probe images, and against ten other undisguised subjects' probe images both for 2D passive image only matching and for our 2D+3D image matching. The results for the 2D+3D face imager EDU show good robustness against disguises and against false cross matching for this limited data set, except for the case of the subject wearing a burqa for which the occlusion of the face was too great for good matching. The 2D passive image only matching had trouble with two other disguises in addition to the burqa.



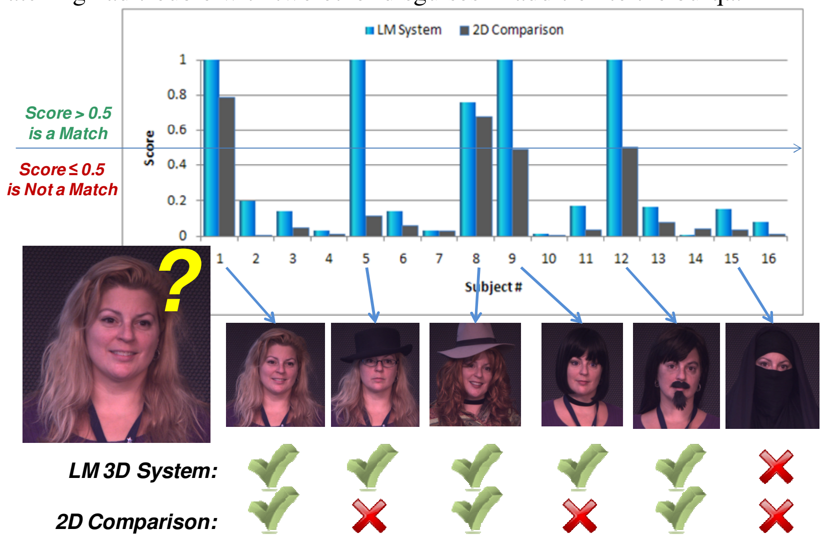
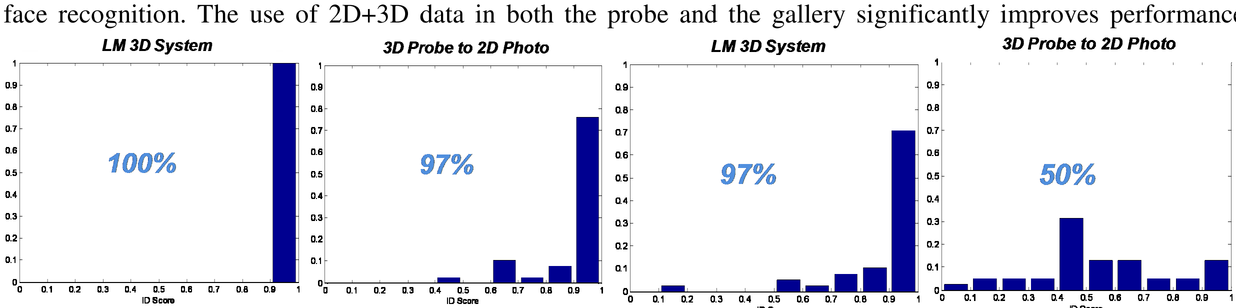


Figure 1. Engineering Development Unit. **Figure 2.** Engineering Development Unit Identification Test Results

Figure 3 shows the normalized histograms of matching scores for the entire set of 40 subjects (no disguises) for the cases of brisk walking speed with frontal facing pose and with right facing pose (~25°-30° from frontal), comparing our system's performance when both the gallery and probe 2D+3D images are collected by the EDU versus when the probe is collected by the EDU, but the gallery image is only a 2D photograph. The percentage of scores above 0.5 (i.e., matching scores) are annotated in each graph. The EDU does quite well in these cases even when the gallery is only a 2D photo, except for the off-axis pose case, which has historically been a problem for 2D face recognition. The use of 2D+3D data in both the probe and the gallery significantly improves performance.



Frontal Facing Pose **Frontal Facing Pose** **Right Facing Pose** **Right Facing Pose**

Figure 3. Normalized histograms of matching scores for 40 subjects at 10-m range, brisk walking speed, & 2 poses.

The test results show that the EDU has met the goals of 3D face capture at >20-m standoff distance, <1.4-mm lateral resolution (at maximum range), <1-mm range precision, and real-time capture at 1-Hz update rates for brisk walking speed (up to ~1.5 m/s), minimally cooperative subjects. The EDU uses technologies and techniques that are potentially low cost in production. The EDU is now ready for off-site data collections and demonstrations.

4. References

[1] M. Takeda, H. Ina, and S. Kobayashi, "Fourier-transform method for fringe-pattern analysis for computer-based topography and interferometry," JOSA, 72, pp. 156-160 (1982).