Lodz University Of Technology
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Advanced Biometric Data Acquisition in Less-Cooperative Environments (Synopsis)

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Łódź, 2019

Thesis Focus and Scope

Over the last years, the number of biometric identification systems has been increasing significantly. Such systems are often designed so that they can successfully operate in non-cooperative scenarios, e.g. [1], [4], [3], [13] or [10]. This means that when the system is operating a person should not even know that they are subject to a recognition process. In fact, this would be an additional step forward in security and monitoring tasks, especially at crowded locations where the risk of terrorist attacks is high and where normal identification methods like ID verification or guarding are not applicable. However, none of the commonly available systems provides a fully non-cooperative approach to identification of people.

Although performance of such systems has been increasing over the last years, the overall accuracy is still insufficient for operating in more challenging applications. The current state-of-the-art in biometric recognition is yielding a trusted results even when dealing with face images with pose variations, facial expressions and occlusions. However, it is still difficult to acquire quality face images from multiple subjects in real time. The existing algorithms used for detection and tracking are not optimized for operating in real time with multiple subjects on scene. Moreover, the majority of solutions offered are based on PTZ cameras which were not designed to operate in such conditions. Because of their mechanical design and high inertia they do not enable fast and smooth operation in wide scene conditions. Thus, the solutions available should rather be called less-cooperative and, as a consequence, there is still space for improvement.

The majority of existing solutions, like [6], [11], [7] are based on master-slave approach. It means that the system is based on two separate vision systems: Wide Field of View (WFOV) and Narrow Field Of View (NFOV). The WFOV vision system is used to observe the entire scene to find a potential subjects that could be identified. The NFOV vision system is used to target into a specific point of the scene to acquire a high resolution face image of found subject.

In recent years, a growing tendency towards using a reduced number of cameras has emerged. The solutions proposed, like [9], [12], [2], [8] or [6], rely on a single camera for locating subjects within the scene. What is more, recognition systems based on stereo vision have been discredited in recent years by some authors:

- In 2005 Guo et al. [5] wrote: "Traditionally, a laser range finder or stereo techniques (using two or more cameras) can be used to obtain the depth of an object to the camera. This adds further cost and complexity to the system."

- In 2013 Park et al. [7] wrote: "A direct estimation of the depth using a 3-D sensor or stereography method could be a possible solution, but they are either too expensive or not sufficiently accurate".

- In 2015 Neves et al. [6] wrote: "(...) without using stereographic reconstruction, which is not feasible in real-time applications" and "(...), these systems either rely on stereographic reconstruction, which is computationally expensive, or dispose the cameras in a specific configuration to ease object triangulation, which is not practical for real-world scenarios."

Therefore, a different approach to less-cooperative recognition system is presented in this thesis. The author presents a solution based on stereo vision that could work with high precision in real time conditions using inexpensive off-the-shelf WFOV cameras and a standard personal computer for processing. Additionally, this solution employs a novel NFOV lens in order to overcome the drawbacks of typical PTZ cameras.

The research was funded by Polish National Centre for Research and Development in the frame of the project LIDER/027/591/L-4/12/NCBR/2013, entitled: "Non-Cooperative bio-Metric system for Positive AuthentiCaTion" (COMPACT) and accomplished at Department Of Microelectronics and Computer Science. Besides the Author, the research team consists of Kamil Grabowski (supervisor), PhD, Wojciech Sankowski, PhD and Michał Włodarczyk, MSc.

The goal of the research conducted was to design and develop a biometric recognition system that could handle multiple authenticated subjects at the same time and would not require significant cooperation from them. The main goals of the COMPACT system are divided into two paths that can be summarized as follows:

- **Biometric traits acquisition** - Damian Kacperski, MSc. (author) Design and development of a biometric traits acquisition system, dedicated for less-cooperative environments. Preparation of an algorithm for detecting and tracking humans that could handle multiple authenticated subjects at the same time without confusing them. Design and development of a solution for obtaining stable lighting conditions during the acquisition process and synchronizing the operation of two independent vision systems: wide field of view stereo vision system, and acquisition lens. Additionally, accurate understanding of a scene, compensating for the subject's motion and targeting the acquisition lens to capture high-quality features.

- **Biometric recognition** - Michał Włodarczyk, MSc. - Research on biometric recognition algorithms suited for less-cooperative environments. Adapting algorithms for using biometric traits obtained by the acquisition system developed. Studying face and periocular algorithms. Employing subjects pose estimation in order to reduce biometric identification time.

Main Author Contributions

The main contributions of presented in this thesis research can be summarized as follows:

- A comparative overview of biometric recognition systems dedicated for less-cooperative scenarios was presented. The most common solutions for biometric trait acquisition in such conditions were described. Furthermore, a list of requirements for face, periocular and iris images to be used in biometric recognition was gathered.

- A method for detecting new subjects within the scene and tracking them was presented. An implementation was dedicated for unconstrained scenarios. The proposed solution takes into account the real-time requirements of the system and the constraints of hardware computational power. The efficiency of each step of processing was compared with performance of the state-of-the-art algorithms.

- A novel method for face detection matching in stereo vision camera environments was presented. An implementation was based on the use of face key points, stereovision data and three-dimmensional models processing. A comparative analysis employing a state-of-the-art algorithm revealed a significant improvement in accuracy and a reduction in processing time. Furthermore, the solution proposed exhibits an excellent ability to reject improper face detections.

- The benefits of stereo vision recognition systems were identified and confirmed. The results obtained demonstrated that precise information on scene of subject location obtained from a stereo vision system could improve the accuracy and effectiveness of subject tracking and detection.

- A novel biometric trait acquisition method based on the innovative NFOV lens was presented. The Author designed and developed all the hardware and software components used for NFOV lens management. Furthermore, the Author made a significant contribution to the solution creation process, including prototype development.

- An innovative system for camera triggering and for management of dynamic lightning conditions was designed and developed. The solution proposed allows connecting multiple cameras and integrating them with external infrared illumination sources. Furthermore, the system allows combining and synchronizing two independent vision systems that operate in different light spectra (visible light and near infra-red light) so that they do not interfere with each other. The result obtained showed desirable stable lighting conditions on the NFOV images obtained.

Doctoral Thesis

1. **First thesis:** The design that combines a lens with an external pupil and galvanometric mirrors allows acquiring biometric images of quality that is sufficient for performing biometric identification on-the-move and at-a-distance.

2. **Second thesis:** The application of a simplified three-dimensional face model, calculated with the use of face key points and stereovision data allows increasing the accuracy and decreasing the processing time of people tracking algorithm.

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