Modern System for Face Biometrics Data Registration

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Abstract. The unambiguous identification of persons is one of the key aspects of police work. Biometric data find their application here due to the uniqueness of personal characteristics, which has a decisive impact on the certainty of identification of a person under investigation. Both the expansion of the set of biometric characteristics and advances in the quality (accuracy) of their representation in archives affect the correctness of identification and increase the chances of identification based on even fragmentary data. Through the practical application of modern technology, we can achieve significant advances in the effectiveness of person identification for forensic purposes and the search for missing persons.

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Introduction

According to Article 4 of the EU-wide General Data Protection Regulation (GDPR or its Polish equivalent, RODO, the Personal Data Protection Regulation), Section 14, the term ‘biometric data’ means such personal data that results from specific technical processing, related to the physical, physiological or behavioural characteristics of a natural person and allow or confirm the unambiguous identification of that person, such as a facial image or dactyloscopic data.1

A person’s biometric data can be obtained by recording the selected characteristics that identify the person and are unique to him or her, such as fingerprints, retina, face or ear shape, voice, DNA pattern, handwriting sample, behaviour, facial expression, gestures, etc. In order to provide an unambiguous way of interpreting such data and performing identifications of individuals based on them, it is necessary to use appropriate processing techniques. In practice, this means taking and capturing

1 Rozporządzenie Parlamentu Europejskiego i Rady (UE) 2016/679 z dnia 27 kwietnia 2016 r. w sprawie ochrony osób fizycznych w związku z przetwarzaniem danych osobowych i w sprawie swobodnego przepływu takich danych oraz uchylenia dyrektywy 95/46/WE (ogólne rozporządzenie o ochronie danych) Dz. Urz. UE L 119 z dn. 4.05.2016 r., s. 1, https://uodo.gov.pl/pl/404/224, [accessed: 18/07/2023].
a person’s ensemble template or selected biometric trait. In the modern world, such biometric templates usually exist in digital form, as a record of, for example, a fingerprint, a writing sample, a DNA record or a facial image. This facilitates their storage, access and manipulation of the data according to the needs of the relevant services.

In the work of law enforcement, the collection, storage, verification and identification of biometric data is crucial. A digital template containing the biometric information in question is compared with an evidentiary sample to verify the similarity and possibly confirm the identity of the individual.2

The rich set of biometric data is very useful in criminal cases, where, based on the crime scene traces found, which are most often fragmentary, there is a need to check and possibly assign the evidence to a record from a database in the archive and thus identify a suspect or narrow down the list of possible suspects. Also, when searching for missing and wanted persons, the collected biometric data render invaluable services by helping to unambiguously compare the characteristics of the material examined with the patterns already stored in the archives.

Biometric data are also used in security procedures in public transport, e.g. at airports3, in migration procedures4, in health care5, in the work of the military6 and in election procedures7. They are also increasingly used in commercial applications8.

As part of the work carried out on a complementary biometric identification system, in addition to the standard, well-known and widely used techniques for recording and archiving biometric data, such as fingerprint, DNA and facial image data, a state-of-the-art image data acquisition and processing technique was used, based on which a stand for the automated acquisition of 3D image data was built. Because of its intended use, the 3D image data collected in the stand

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must have high fidelity with reality, so it is essential that the system performs measurements (i.e. determines the actual coordinates of points) and not interpolation or approximation.

THE SYSTEM

The automated image acquisition system is part of a broader solution that has been developed under the NCBR project No. DOB-BIO10/09/01/2019 entitled ‘BIOMETRY — The development of a technologically advanced information system enabling automated processing of information collected in forensic biometric databases to combat crime or identify persons’.

It has been built with the assumption that trained personnel will be appointed to operate it, with the operations they will have to perform not requiring specialist knowledge related to 3D scanning.

The stand is designed for people of varying personal characteristics, such as weight, height, physical build, etc. It is self-contained — the entire measurement procedure takes place within the unit — and no additional components supporting image data collection are needed.

It offers automated operation, with the measurements being performed without operator intervention. The requirement is that the person being scanned, once seated in the measuring station, maintains his or her position during the measurement process, and the operation of the station consists only of the initial positioning of this person in relation to the measuring head, with the rest taking place automatically. The measurement result is presented as a point cloud reflecting the actual dimensions of the test person’s head and shape.


Acquisition of an image in three-dimensional form involves the application of one of the known and proven shape measurement techniques. The registration process takes a few tens of seconds and requires no operator intervention during the process. It was decided to use a method called structured light projection. Other methods, such as photogrammetry and laser scanning, for example, did not meet the requirements, such as the quality of the 3D image obtained or the required measurement time.

It was decided to use a measurement sequence consisting of six frames of sinusoidal fringe projections and eight frames of Gray code projections. The last step in the sequence is the texture acquisition, performed under diffused white light. This procedure reduces the measurement time to a minimum while maintaining high accuracy of the subject’s head shape reproduction.

A complete measurement sequence for one direction consists of a stripe and texture image acquisition phase using two projectors and three cameras. Once the images have been collected, they are processed. Initially, the phase and modulation parameters of the striations are determined, which are then subjected to a noise extraction procedure (in simple terms: correction of step changes that result from the nature of the measurement method). Once the noise is removed, the shape is reconstructed and a point cloud is generated. The reconstruction procedure for a single projector-camera pair is shown schematically in Fig. 1.

Fig. 1. Schematic diagram of the data reconstruction process for a single projector-camera pair

Source: Authors’ own elaboration
As part of the design work, several versions of the spatial configuration of the camera and projector system were proposed, taking into account the requirements arising from the statistical distribution of human anthropometric data. Based on a series of simulations of the measurement system, the optimum configuration for the measuring head was selected and designed, then manufactured and assembled. The internal structure of the measuring head was based on a frame assembled from high-stiffness aluminium profiles which were mechanically disconnected. Mountings for active components, *i.e.* cameras and projectors, were installed at the structural points provided. This solution ensures sufficient rigidity (stability of the position of the active components) and resistance to vibration for proper operation.

Fig. 2 shows the design for the construction of the complete measuring station and Fig. 3 shows the assembled station during test work.

*Fig. 2. View of the construction of the complete measuring station*

1 — rotating platform on which the seat is placed, 2 — floor of the measuring chamber, 3 — measuring head (cf. Fig. 3, 4 — sources of white light, 5 — actuators setting the height of the measuring head position. Measuring head 3 contains the elements of the shape measuring system: C1—C4 — image acquisition cameras (camera C4 is behind the white light source 4), P1, P2 — structured light projection systems.

*Source: Authors' own elaboration*
The shape measurement procedure requires that the position of the measured person’s head be fixed with respect to the camera axis C1 from Fig. 2. This requires changing the mutual position of the measured person’s head and the measuring head along the y-axis (height). To simplify its construction and reduce the complexity of its operation, it was decided to suspend the measuring head on actuators, allowing the head to be repositioned without the need to manipulate either the seat or the measured person (item 5 of Fig. 2). In addition, such a solution, apart from the obvious advantage of moving the chair or the entire floor of the measurement chamber with the seat, makes it possible to efficiently operate the device remotely while checking the correctness of the device setting on a preview monitor.

The next step was to design white light illumination to ensure texture acquisition. The intensity of the illumination must allow both a short exposure time and repeatability throughout the procedure. The nature of the illumination, in turn, must ensure both uniformity of illumination of the object to be measured, i.e. the human head, and avoid shadows. Using commercial professional flashlamps with a generator was chosen to ensure the shortest possible lamp loading time between flashes. The lamp heads were fitted with softboxes with diffusers — item 4 in Fig. 2 (for practical reasons, the white light source on the other side of the measuring head was omitted from the figure). This provided a large source area and eliminated unnecessary shadows. The use of two lamps placed symmetrically with respect to the y-axis of the measuring head ensures high uniformity of illumination of the object.

The design of the bench floor includes a system for angular positioning of the chair relative to the measuring head — a built-in swivel and a chair bearing system (item 1 in Fig. 2). This allows a series of measurements to generate a full, three-dimensional representation of the measured person’s head shape in virtual form (point cloud).

Fig. 3. View of the assembled measurement setup of the Fotosfera system during testing

Source: Authors’ own elaboration
The automated three-dimensional-data image measurement station is intended to represent the full body of the test person’s head, so it is necessary to acquire a sufficient number of points covering the full 360° view. The station carries out measurements for a series of views of the subject’s head together with a rotation of the chair. The shape data obtained from the successive views are automatically combined. The final result of the merging can be seen in Fig. 4.

**Fig. 4.** Point cloud visualisation representing the image of a person contributing to the Fotosfera system (view from the window of the dedicated software)

**Conclusions**

By representing the shape of the subject’s head and the texture, it is possible to obtain a virtual model of the person’s head that can be manipulated in different ways. An undoubted advantage of such a solution is that the collected biometric data reflect the full omnidirectional shape of the head, which is a unique individual feature, and the actual dimensions in the form of three-dimensional coordinates (x, y, z), so it is possible to determine identification parameters without the participation of the person, but only based on the collected and archived data set.
Another advantage of the virtual model image is the ability to view the head from any perspective (i.e. from any direction and any distance), making it possible to generate any situational view based on biometric data collected in this way, for any focal length of the virtual camera.

The station for automated measurement of the full, three-dimensional image of persons is currently the most modern system for acquiring and archiving image data of persons in Poland.

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Streszczenie. Jednoznaczna identyfikacja osób jest jednym z kluczowych aspektów pracy policji. Dane biometryczne znajdują tu swoje zastosowanie ze względu na niepowtarzalność cech osobowych, co ma decydujący wpływ na pewność identyfikacji badanej osoby. Zarówno poszerzanie zbiorników biometrycznych, jak i postęp w jakości (dokładności) ich odwzorowania w archiwach wpływają na poprawność identyfikacji i zwiększają szanse na identyfikację na podstawie nawet fragmentarycznych danych. Dzięki praktycznemu zastosowaniu nowoczesnych technologii jesteśmy w stanie osiągnąć znaczący postęp w skuteczności identyfikacji osób na potrzeby kryminalistyki i poszukiwań osób zaginionych.

Resumen. La identificación inequívoca de las personas es uno de los aspectos fundamentales del trabajo policial. Los datos biométricos encuentran aquí su aplicación debido a la unicidad de los rasgos personales, que tienen un impacto decisivo en la certeza de la identificación de la persona investigada. Tanto la ampliación del conjunto de características biométricas como los avances en la calidad (precisión) de su reproducción en los archivos afectan a la corrección de la identificación y aumentan...
las posibilidades de identificación a partir incluso de datos fragmentarios. Gracias a la aplicación práctica de la tecnología moderna, podemos hacer avances significativos en la eficacia de la identificación de personas para la ciencia forense y la búsqueda de personas desaparecidas.

Zusammenfassung. Die eindeutige Identifizierung von Personen ist einer der wichtigsten Aspekte der Polizeiarbeit. Biometrische Daten finden hier ihre Anwendung aufgrund der Einzigartigkeit der persönlichen Merkmale, die einen entscheidenden Einfluss auf die Sicherheit der Identifizierung der untersuchten Person hat. Sowohl die Erweiterung der Menge biometrischer Merkmale als auch die Fortschritte bei der Qualität (Genauigkeit) ihrer Wiedergabe in den Archiven beeinflussen die Richtigkeit der Identifizierung und erhöhen die Chancen der Identifizierung auf der Grundlage selbst bruchstückhafter Daten. Durch die praktische Anwendung moderner Technologien sind wir in der Lage, die Effizienz der Personenidentifizierung in der Forensik und bei der Suche nach vermissten Personen erheblich zu steigern.

Резюме. Однозначная идентификация личности - это один из ключевых аспектов работы полиции. Биометрические данные находят здесь свое применение благодаря уникальности персональных черт, что оказывает решающее влияние на уверенность в идентификации человека. Как расширение набора биометрических характеристик, так и повышение качества (точности) их воспроизведения в архивах влияют на правильность идентификации и повышают шансы на установление личности на основе даже фрагментарных данных. Практическое применение современных технологий позволяет значительно повысить эффективность идентификации личности в криминалистике и поиске лиц, пропавших без вести.