A Taxonomy of Biometric Methods
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Abstract. In this paper we shall introduce a taxonomy of biometric methods continuing thereby our previous research on selected segments of biometrics. We show how our previously developed systematization and categorization of biometric methods, characteristics and models can be extended by building upon an open ontology of biometrics. The developed taxonomy inherits its openness and extendibility as well as its consistency from the systematization, adding new insights at the same time. We add a new dimension, namely biometric samples, to our previous framework built upon biometric characteristics as well as the general biometric system developed by Wayman and extended in our research.

Keywords. taxonomy, biometrics, method, sample, ontology

1. Introduction

Taxonomy coming from the Greek ταξις (taxis) for order and νομος (nomos) for law or science is the science and practice of classification. Taxonomies, or taxonomic schemes, are composed of taxonomic units or taxa, which basically are kinds of things that are arranged frequently in a hierarchical structure, typically related by subtype-supertype relationships. Maybe the most popular example is the numerical taxonomy initially developed by Sneath and Sokal that establishes a classification of organisms based on their similarities [7].

In this paper we continue our research on the essence of biometric methods by introducing a new taxonomy of biometric methods. In [2] we showed how it is possible to apply a general system theory approach to the general biometric identification system developed by Wayman [8] and presented on figure 1 in order to extend it to be applicable to unimodal as well as multimodal biometric identification, verification and classification systems. By analyzing the developed model especially the inputs and outputs of the system’s elements three types of biometric methods where introduced depending on their function: (1) feature extraction methods, (2) quality control methods, and (3) recognition methods.

By categorizing biometric characteristics into physical and psychological (behavioral) ones we were able to classify any biometric
method depending on its function and biometric characteristic that is used for recognition. This systematization has the advantages to be open (e.g. new biometric methods as well as new biometric characteristics can be added at will), to be consistent (by adding new methods and/or characteristics the structure of the systematization remains), to make a distinction between biometric methods and biometric models possible (methods cover only one field in the systematization, while models cover at least two in the same row) and makes it possible to discover fields of potential future research (empty fields in the table). Table 1 shows an outline of the previously developed systematization.

Table 1. Outline of the developed systematization

<table>
<thead>
<tr>
<th>Feature Extraction</th>
<th>Quality Control</th>
<th>Feature Recognition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retina</td>
<td></td>
<td></td>
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<tr>
<td>Retinal signature feature extraction</td>
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<tr>
<td>Template matching</td>
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<tr>
<td>Behavioral</td>
<td></td>
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<tr>
<td>Hand grip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Template matching</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In [3] we argued that there is a need for an open biometrics ontology that was afterwards partially build in [1] and [6]. During the development of this ontology crucial concepts like biometric system, model, method, sample, characteristic, feature, extracted structure as well as others were defined. This research showed that the previously defined systematization can be extended to form a taxonomy of biometric methods.

2. Basic Definitions in Biometrics

In order to reason about biometrics we need to introduce some basic definitions of concepts used in biometrics. These definitions were crucial to the development of a selected biometrics segments ontology as well as the taxonomy as argued further.

First of all, we can approach biometrics in a broader and in a narrower perspective. In the broader perspective biometrics is the statistical research on biological phenomena; it is the use of mathematics and statistics in understanding living beings [4]. In the narrower perspective we can define biometrics as the research of possibilities to recognize persons on behalf of their physical and/or behavioral (psychological) characteristics. We shall approach biometrics in the narrower perspective in this paper.

A biometric characteristic is a person’s physical or behavioral characteristic that can be used in order to recognize the person. Physical characteristics are characteristics that one is born with (like a person’s face, iris, retina, finger, vascular structure etc.). Behavioral or psychological characteristics are characteristics that one acquires or learns during her life (like a handwritten signature, a person’s gait, her typing dynamics or voice characteristics).

The word method comes from the Greek μεθοδος (methodos) that literally means “way or path of transit” and implies an orderly logical arrangement (usually in steps) to achieve an attended goal [9, 29]. Thus a biometric methods is a serious of steps or activities conducted to process biometric samples of some biometric characteristic usually to find the biometric characteristic’s holder.

A model is a (not necessarily exactly) image of some system. It’s main purpose is to facilitate the acquiring of information about the original system [5, 29]. A biometric model is thus a sample of a biometric system that facilitates the acquiring of information about the system itself as well as information about person’s biometric characteristics.

A sample is a measured quantity or set of quantities of some phenomena in time and/or space. Thus a biometric sample represents a measured quantity or set of quantities of a biological phenomena (in the broader perspective) or a biometric characteristic (in the narrower one). In [6, 35] a UML1 model of

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1Unified Modeling Language
possible biometric samples was developed as shown on figure 2.

Seven types of biometric samples were found in contemporary scientific literature, namely (1) audio samples, (2) video samples, (3) video sequences, (4) image samples, (5) hyperspectral samples, (6) multispectral samples as well as (7) environment data samples.

Some of these classes of samples need further explanation. A video sequence consists of a set of ordered image samples. A video sample consists of a video sequence and the corresponding audio sample. Environment data samples are all kind of samples that cannot fit in any of the other classes (typing dynamics time sequences, mouse move dynamics time sequences, hand grip pressure samples for example to name a few).

The type or class of biometric sample is important when talking about biometric methods. Methods are often specifically designed for a special type of sample especially feature extraction methods. The idea to categorize biometric methods on behalf of biometric samples they use is thus natural.

3. Taxonomy of Biometric Methods

In the following we shall introduce a new dimension to our previously defined systematization, the dimension of biometric samples following their definition in the open ontology of selected biometrics segments [6]. The model of the taxonomy is shown on figure 3.

As one can see, we classify biometric methods according to three criteriae: (1) the biometric characteristic the method uses, (2) the type of the method when taking it’s function into consideration, and (3) the type of sample it uses.

If we formalize this taxonomy we can state that any biometric method can be classified with it’s three coordinates or formally \( M(c, f, s); s \in \mathbb{I} \cup \mathbb{W}, \ f \in \Phi \) and \( s \in \Omega \).
where $\mathbf{P}$ is the set of all physical characteristics ($\mathbf{P} = \{\text{arm}, \text{deoxyribonucleic acid}, \text{ear}, \text{electro-cardiograph}, \text{face}, \text{feet}, \text{finger}, \text{hair}, \text{head}, \text{hyperspectral tissue images}, \text{iris}, \text{lips}, \text{nail}, \text{o-to-acystic emissions}, \text{palm}, \text{retina}, \text{skin spectroscopy}, \text{sweat pores}, \text{teeth}, \text{thermogram}, \text{toe}, \text{vascular structure}\}$), $\mathbf{B}$ the set of all behavioral characteristics ($\mathbf{B} = \{\text{brain waves}, \text{hand grip}, \text{handwritten signature}, \text{gait}, \text{mouse move dynamics}, \text{smile}, \text{typing dynamics}, \text{voice}\}$), $\Phi$ the set of the three possible purposes of a biometric method ($\Phi = \{\text{feature extraction}, \text{quality control}, \text{recognition}\}$), and $\Omega$ the set of all sample types ($\Omega = \{\text{audio sample}, \text{environment data}, \text{hyperspectral sample}, \text{image sample}, \text{multiaspect sample}, \text{video sample}, \text{video sequence}\}$).

As one can see we can classify any biometric method according to the three stated criteria. For example the random line tracking method uses the physical biometric characteristic of a person's vascular structure, its purpose is to extract a feature and works on image samples, thus using the developed taxonomy the method would have the coordinates $M_{\text{random line tracking}}(\text{vascular structure}, \text{feature recognition}, \text{image sample})$.

Such a taxonomy yields a unique framework for communication and future research. First of all there are much less possibilities for misunderstanding. For example the eigenvector method has been proven to work on different characteristics and different types of samples which can lead to confusion in a particular conversation. But if one states $M_{\text{eigenvector}}(\text{face}, \text{feature extraction}, \text{image sample})$ there is a clear and precise semantic.

As well as the previously defined systematization this taxonomy shows "blank spaces" that should be filled. These are areas of potential future research on the field of biometric methods.

4. Conclusion

In this paper a taxonomy of biometric systems was developed by building upon a previous developed systematization and an open ontology of selected biometrics segments. The taxonomy allows us to classify any biometric method according to three criteria: (1) the biometric characteristic the method uses, (2) the purpose or function of the method, and (3) the type or class of sample the method processes.

Using the developed taxonomy any biometric method can be defined using three coordinates $M(c, f, s)$ where $c$ represents the used biometric characteristic, $f$ the purpose or function of the method and $s$ the type of sample. The semantic of such a formalization is precise and thus gives a unique framework for communication.

The taxonomy is (1) open (new biometric characteristics, biometric sample types as well as biometric methods and models can be added at will); and (2) consistent (by adding new characteristics, sample types or methods the structure of the taxonomy stays intact). The taxonomy also gives guidelines for future research since there are "blank fields" in it. The meaning of such field is that there up to the current date no biometric method has been developed for the specified biometric characteristic, the specified function as well as for the specified sample type.

Using this taxonomy we were able to find two new classifications of biometric methods. The first which was already outlined in [2], [3] and [6] gives us the possibility to classify biometric methods into (1) characteristic specific methods (biometric methods that are applicable to only one biometric characteristic) and (2) general methods (biometric methods that are applicable to more than one biometric characteristic). The second classification, we outline here, lets us classify biometric methods into (1) sample type specific (biometric methods applicable to only one type of biometric sample) and (2) general methods (methods applicable to more than one type of biometric samples).

Future research in this area shall include
an in depth formalization of biometric systems in general taking this taxonomy as well as the previously defined systematization and the open ontology into consideration.

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