A Method for Ontology Based Evaluation of Biometric Systems in Organizations – Do We Use the Right Biometric Characteristic?

Miroslav Bača, Markus Schatten, Kornelije Rabuzin
Faculty of Organization and Informatics
University of Zagreb
Pavlinska 2, 42000 Varaždin, Croatia
{miroslav.baca, markus.schatten, kornelije.rabuzin}@foi.hr

Abstract. *The paper presentes a method for the evaluation of biometric systems based on an open ontology of selected segments of biometrics. The ontology was developed in F-logic using the* $\mathcal{F}$LORA-2 *system. Descriptive parameters of biometric characteristics as well as organizational contingency parameters are taken into consideration and a metric for grading a biometric system's adjustment with organizational needs – the adequacy level is introduced.*

Keywords. biometrics, evaluation, ontology, characteristic, descriptive, parameter, f-logic

1 Introduction

When evaluating biometric systems that are implemented in some organizations one faces the question: "is the system adjusted with our specific needs, and if yes in what extent?" The basic idea behind this paper is to focus on adjustment to organizational (contingency) needs rather than on performance.

On the other side with every day biometric there are more and more biometric characteristics used in different biometric systems and lots of them are commercially promising. While constructing a systematization of biometric methods, characteristics and models [2] as well as while developing an open ontology of biometrics we were able to identify over 30 different biometric characteristics described in different publications. So another question to ask here is how to identify the most adequate biometric characteristic for a specific organization?

In order to answer the described questions we decided to take an ontology based approach. By developing a formal ontology of some area of interest one is able to reason about concepts and individuals inside this specific domain. Thus an ontology represents a formal description of a set of concepts within a domain as well as the relationships between those concepts.

2 Open Ontology of Selected Segments of Biometrics

In the last decade we faced a great number of publications in the field of biometrics and a lot of new biometric methods, techniques, models, metrics and characteristics were proposed [8, 11, 6, 7, 9, 1]. Due to this explosion of research, scientific and professional papers certain inconsistencies in terminology emerged. What some authors call a biometric method, others call model, system or even characteristic. There wasn't enough effort in creating a unique systematization and categorization which would approach the stated issues and open new areas of research. Thus we developed an open ontology of selected segments of biometrics [3, 12] as well as a taxonomy of biometric [13] methods in order to close this gap as well as to make a step forward in developing a unique ontology of biometrics. The ontology is open in the sense of open source since we do not consider the ontology to be finished ever

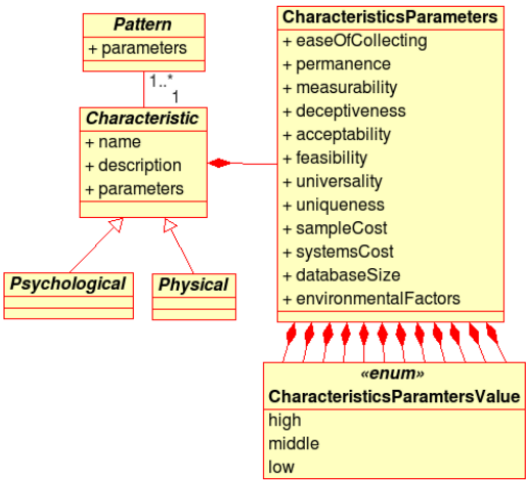

Figure 1: Partial UML diagram of biometric characteristics

```
characteristic [
        name *=> string ,
        description *=> string ,
        params *=> characteristics_params
].
behavioral_characteristic :: characteristic.
physical_characteristic :: characteristic.
```

Figure 2: $\mathcal{F}$LORA-*2* implementation of the class characteristics and some of its subclasses

because new reseach in the field of biometrics will (most hopefully) extend the ontology with new insights.

We used UML[1] to create intital views of this ontology [5] and later on F-logic[2] [10] to implement it [12]. One of these initial views concerning biometric characteristics is shown on figure 1.

We used the $\mathcal{F}$LORA-*2* knowledge representation language [14] to implement the ontology into a computer program as well as to use the strong reasoning engine provided. The following listing on figure 2. shows a part of the implemented ontology concerning biometric characteritics that shows some metadata that we used later for reasoning.

Specific rules and predicates were also implemented to facilitate reasoning about biometric characteritics especially to allow constraints during evaluation like the one shown on figure 3. This

[1]Unified Modeling Language
[2]Frame Logic

```
constraint( ?C, ?P, ?V ) :-
        ?C:characteristic[ params -> ?_P ],
        ?_P[ ?P -> ?V ]
```

Figure 3: A rule that allows flexible constraints inside queries

implementation allowed us to create specific queries for the evaluation of biometric systems.

3 Descriptive Parameters and Evaluation Criteriae

To provide a framework for evaluation we used descriptive parameters of biometric characteristics [4] as well as corresponding evaluation criteriae shown in table 1. In the developed ontology every biometric characteristic was described through metainformation about its possible parameters. These parameters are defined as fuzzy sets (high, medium, low) since one cannot define these parametrs exactly since they depend on different biometric methods that are used in a specific biometric system.

By evaluating a specific situation one has to have these criteriae in mind when analyzing some organization's needs with regard to biometric system implementation. Depending on the particular organization some of these criteriae will be more and some will be less important an so will the parameters in the evaluation query as argued further.

4 Distance from the Ideal Solution

In order to perform evaluation one needs to establish an adequate metric to measure the adjustment of a biometric system with a certain situation. To do so we introduced the term ideal solution to be the set of possible biometric characteristics that fit best to the given constrants defined by a particular organization with regard to the knowledge that is implemented into the ontology. Since the ontology is open this ideal solution is time dependent and dynamic with regard to current state of biometrics science.

Table 1: Descriptive parameters of biometric characteristics with corresponding evaluation criteriae

Parameter	Evaluation Criteria
Ease of collecting	If performance is important (especially time and cost)
Permanence	If the same users are going to use the system for a relatively long period of time
Measurability	If security and performance are important
Acceptability	If user's satisfaction is important (e.g. customers)
Deceptiveness	If security is important and there is a reasonable probability of eventual fraud attempts
Feasibility	If cost is important or if the organization is very specific in terms of needs
Universality	If the system is to be used in lots of different situations (security, transactions etc.)
Uniqueness	If the number of possible users is potentially big and security is important
Sample cost	If the number of possible users is potentially big and cost is important
System cost	If the number of possible users is potentially small and cost is important
Database size	If the number of possible users is potentially big and performance is important
Environmental factors	If the system is to be used in lots of different situations (environmental, weather etc.)

In order to aquire an ideal soultion for a particular situation one needs to issue a query in F-logic that has the form as shown on figure 4.

Whereby the variable `?Characteritic` will be bound to the name of the ideal biometric charactaristic with regard to the knowledge in the ontology, and it holds that:

```
constraint ( ?_Characteristic , P_1, V_1 ) ,
constraint ( ?_Characteristic , P_2, V_2 )
...
constraint ( ?_Characteristic , P_n, V_n ) ,
?_Characteristic[name âĹŠ> ?Characteristic ].
```

Figure 4: The form of the query to construct an ideal solution

$$P_1, P_2, ..., P_n \in \{$$
$$\text{ease of collecting, permanence, measurability,}$$
$$\text{deceptivenes, acceptability, feasibility,}$$
$$\text{universality, uniqueness, sample cost,}$$
$$\text{system cost, database size, environmental factors}$$
$$\}, \text{ and}$$
$$V_1, V_2, ..., V_n \in \{\text{low, medium, high}\} .$$

The issued constraints have to be ordered by priority. Now we can define the distance from the ideal solution as the number of necessary mitigations of the initial query in order to find the implemented (or proposed) biometric characteristic in the answer to the query.

A constraint mitigation is defined as the adjunction of a constraint analogous to the lowest priority constraint into the query by the following rules:

- If the constraint with the lowest priority has the form `constraint( ?_Characteristic, P, V )` then this constraint is exchanged with a disjunction having the form `( constraint( ?_Characteristic, P, V ), constraint( ?_Characteristic, P, V`$^+$ `) )` where `V`$^+$ denotes the next possible value if such exists depending on the direction. If no such value exists than the whole constraint is left out. For example if the constraint with the lowest level had the value low, and the direction is the lower the stricter then the next possible value is medium. In turn if the value was medium and the direction is the higher the stricter then the next possible value would be low. On the other hand if the value was high and the direction the lower the stricter that the whole constraint would be left out.

- If the constraint with the lowest priority has the form `( constraint( ?_Characteristic, P, V ), constraint( ?_Characteristic, P, V`$^+$ `) )` it has to be left out.

From this reasoning we can conclude that this algorithm for the distance from the ideal solution lets us construct a adequacy scale for some biometric characteristic with regard to the defined conditions. This adequacy scale has $C \times 3$ levels where C

is the cardinal number of the set descriptive biometric characteristic's parameters. If this set remains constant than the scale has 36 levels of adequacy whereby we denote the level of adequacy with the glagolitic letter Ⰰ (A) for adequacy.

5 Conclusion and Future Research

In this paper we showed a simple method for the evaluation of biometric systems in organizations by using an open ontology of selected segments of biometrics. We used descriptive parameters of biometric characteristics and defined evaluation criteria that can be used as guidelines for the construction of evaluation queries.

We also presented the concept of an ideal solution with regard to the knowledge embedded into the ontology as well as an algortihm for finding the distance from such an ideal solution. This distance we call adequacy level (Ⰰ) and represents a metric for evaluating biometric systems based on descriptive biometric characteristic's parameters that has (if the number of parameters remains constant) 36 levels. The system is more adequate as this level is lower.

Future research in this field shall include a more sophisticated ontology of biometrics as well as an open implementation of this ontology that would be web accessible.

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