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Support Platform for Learning about Multimodal Biometrics

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Abstract: Lately, there is an increasing interest in multimodal biometric systems. Faculty of organizational sciences and Ministry of Education and Science of Serbia have recognized importance of biometrics, and started an international project named "Multimodal biometry in identity management". As a part of our project, we have developed a support platform for learning about multimodal biometrics. Platform is used as part of biometric course in order to improve student's learning experience and to increase their interest in biometrics. A research study was conducted to compare traditional learning method and learning method based on our support platform. Results of our research study speak in favour of using elBio support platform as a teaching tool.

Keywords: biometrics, learning tool, support platform
Categories: K.3, L.2, L.3.6

1 Introduction

In the last decade, the need for large scale identity management systems has dramatically increased. People travel more often, in densely populated areas such as Europe they cross their state border several times per year. They change their living location in order to find better job or to have an opportunity for better education. Moreover, a significant part of our everyday lives is done remotely. Online shopping, use of e-government services, business transactions, social networks are just some of the examples. A common characteristic for all these examples is a need for reliable authentication method. Reliable authentication must be established in order to prevent frauds and unauthorized access to sensitive data, because such events can have dire consequences.

Traditional methods for establishing a person's identity are usually based on using passwords or tokens. Unfortunately, these methods have several disadvantages. Passwords are often used irresponsibly. Either they are designed to be easy to remember (and simultaneously easy to crack), or they are safely designed, but stored inappropriately. The problem with tokens is that often they can be intercepted and stolen. Therefore, there is a need for an alternative approach, where biometric technologies can prove worthy. They provide the computer systems with the ability to identify a person using its physical or behavioral characteristics [Jain, Ross and Prabhakar, 2004]. The main advantage of biometrics in comparison to passwords and tokens is the fact that biometric identity provides the information on who you are, rather than what you know(passwords) , or what you possess(tokens). However, as biometric recognition relies on statistics its output is not a yes/no decision but matching score. This is a big disadvantage of biometrics as it leaves room for errors. Thus, there is a need to constantly improve precision of biometric systems.

University of Belgrade, Faculty of organizational sciences and Ministry of Education and Science of Serbia have recognized importance of biometrics application in identity management. As a result, project named "Multimodal biometry in identity management" was started [MMBIO Project, 2012]. Participants on the project are Ministry of Interior of Serbia and Energoprojekt Holding, a complex business system with activities in Serbia and over 70 countries around the world. Research on the project is oriented towards the analysis of multimodal biometrics and its application in establishing an effective and efficient identity management system.

Project has several important objectives set in different areas of expertise. An important objective is development of new, improved unimodal biometric algorithms, especially for non-intrusive biometric modalities such as face and gait. A new approach based on usage of Microsoft Kinect and content based image retrieval was proposed [Milovanović, Minović and Starčević, 2012]. Multimodal biometrics has also been considered as an important research topic. By integrating data gathered from several different biometric modalities, it is possible to create a precise and secure system even when using open source biometric solutions. Performance gain achieved by using multimodal approach is especially beneficial when using non-invasive biometric modalities. Speaker and face recognition alghorithms are inherently less precise than some more traditional biometric modalities such as fingerprint. However, there is an issue of interoperability between different biometric solutions, acquisition devices and databases. Therefore, an interoperability framework for multimodal biometry has been developed [Milovanović, Minović and Starčević, 2012]. By using the framework, system architects can shorten the time needed to develop a multimodal biometric system.

Besides mentioned, project "Multimodal biometry in identity management" also has other ongoing research activities. Some of them are development of evaluation framework for multimodal biometrics, new algorithms for information fusion in multimodal biometrics, UML (Unified Modeling Language) profile for biometrics, application of multimodal biometrics in mobile applications, etc. All ongoing activities have significant importance as independent parts of the project. Nevertheless, they all serve the main project goal which is the application of multimodal biometrics in identity management. Currently, identity management systems tailored to the needs of project participants are under development.

In order to promote biometrics and identity management among our students, we held a few presentations with these topics. Promotion goals were to introduce our students with this research area, and to eventually find potential associates for the project. However, multimodal biometrics, as a complex research area has a specific terminology, and contains many domain specific definitions. Consequently, some of the biometric novices had a hard time accepting new knowledge, and also had problems with motivation. In order to overcome this issue, we propose an interactive approach for learning of multimodal biometric recognition process. elBio, support platform for learning about multimodal biometrics, has been developed in order to help solving the existing issue.

In the next section, a brief overview of present biometric courses has been given. In section III the problem statement is described. Section IV contains overview of elBio support platform and its functionalities. In section V we have described our research study, where we presented study settings, methodology used and profiles of participants. Section VI discusses research study results. In the last section, paper conclusions are given.

2 State of the art

In 2001, the MIT Technology Review named biometrics "one of the top ten emerging technologies that will change the world" [MIT Technology Review, 2001]. And inevitably the world is changing. The importance of biometric technology is evident in many different areas. Information technology incorporates biometrics in order to establish people's identity. It is an emerging field of technology using unique and measurable physical, biological or behavioral characteristics that can be processed to establish identification, to perform identity verification or to recognize a person through automation [Woodward, Orlans and Higgins, 2002]. Although biometrics is an interesting research field in military and civilian application, true commercial development and use of this technology depends on education of future engineers in this area. It is important to integrate biometrics as a field of study into curricula of Information Technology university programs.

There are several successful examples of incorporating biometrics research area into university curricula, most of which are in USA. Specifically, West Virginia University has created the first undergraduate program in biometrics [West Virginia University, 2004]. Students that finish this course are rewarded with Bachelor of Science degree in Biometric Systems. On the U.S.Naval Academy, Electrical Engineering Department has developed and introduced a biometric course [Ives, Robert, Yingzi, Delores and Thad, 2005], which includes a biometric signal processing laboratory, specifically designed to support the course. In Europe, University of Hertfordshire, UK, offers a Masters Degree course in Biometrics and Cybersecurity [University of Hertfordshire, 2012] and also University of Kent, UK includes Biometric technologies in their MSc course in Information Security and Biometrics [University of Kent, 2012].

However, it is very difficult to properly integrate biometrics into university curriculum as it is a cutting edge research area. Considering the preceding statement and keeping in mind the fact that biometrics is a complex area, there is a need to somehow simplify this topic but yet maintain (or upgrade) the quality of the

biometrics course. Significant help in providing quality can be found in using advanced simulation tools that will enable students to interrogate models and principles in practice [García-Peñalvo, Colomo-Palacios, García and Therón, 2012].

Simulation based platforms for learning specific topics are not new, and there are many examples in different application areas. For example, CryptTool [CrypTool, 2012] can be used for learning cryptography, and Graphical Network Simulator [GNS3, 2012] is designed to improve process of learning network administration. In the field of biometrics, this approach could be used to simulate the development process of biometric systems.

3 Problem statement

One of the goals of our project was to promote topics of biometrics and identity management among students at our faculty, and encourage them to find out more about these research areas. As biometrics is an emerging technology of significant importance, it is useful for future engineers to acquire state of the art knowledge in this scientific area. Also, promoting research areas mentioned is beneficial for the project – "Multimodal biometry in identity management", because it is easier to find highly motivated associates for possible collaboration.

To achieve that goal, several presentations focused on topics of biometrics and development of multimodal biometric systems were held. Although this attempt was somewhat successful, we were not satisfied with some of the feedback received from our students.

In our presentations, traditional teaching approach was used. Students were gathered in the classroom, and one of our colleagues was lecturing, using a slide show presentation shown on a projector. Albeit the members of the audience have been encouraged to ask questions, their response was somewhat meek. Some of the student feedback stated that at some points of presentation they were losing focus, and others suggested that there was a lack of interactive content in the lectures.

Biometrics as a complex research area has a specific terminology, and contains many domain specific definitions. Consequently, it would take some time for biometrics novice to become familiar with the core concepts in this research area. Also, in order to successfully adopt significant amount of new information, they needed to stay highly determined during the learning process. To ensure high motivation of members of our audience we needed to make some adjustments to the learning process. We have identified three key issues connected with the traditional concept of learning.

First issue is the absence of interactive content. Our biometric trainees suggested that they would like to participate more actively in the learning process, not just listen to the lecture. Second issue would be more control over the flow of learning process. When watching slide show presentation, everyone has to keep up with the presenter's lecturing tempo. However, some students prefer to take more time when they adopt new knowledge, and other prefer faster learning. Also, there is no other way of going back to previous topics, short of asking the lecturer, and therefore interrupting the presentation.

Third issue is the lack of practical activities. Students feel more engaged if they can apply their new knowledge on some type of real world problems or scenarios.

4 elBio overview

In order to improve students' learning experience and to increase their interest in biometrics we have decided to upgrade the existing multimodal biometric system development framework, and transform it to elBio - an interactive biometrics learning platform. elBio gives an introduction to the field of multimodal biometrics through series of interactive steps in form of a tutorial. It is possible to simulate biometrics verification and identification processes and try out different combinations of normalization and fusion techniques.

elBio has been developed using Java programming language and it integrates three different open source biometric libraries: OpenCV [Bradski, 08], MARF [Mokhov, 10] and NBIS [Watson, 10]. For face recognition we have used some of the OpenCV features, voice recognition was performed using MARF and for fingerprint feature extraction and matching we relied on NBIS. The platform architecture is modular and it allows easy introduction of new unimodal biometric solutions.

We have developed elBio architecture based on several generic steps in multimodal biometrics system development, which we identified during our research. The steps we recognized are:

- Choosing a working mode
- Selection of biometric modalities
- Normalization and fusion techniques combination
- Recognition process execution
- Results examination

Learning process in our platform closely follows development life cycle of one multimodal biometric system. In particular, iteration through different stages allows student to grasp important keynotes about every phase of multimodal biometric system development. In this way, knowledge is gained incrementally and after completing all recognized steps student possesses complete insight into the biometric system functionalities.

4.1 Working mode selection

First step in biometric system development is working mode selection. Biometric systems can operate in two different working modes, verification and identification. Additionally, it can be very important to estimate overall system performance, thus we included performance test as an optional working mode. Working mode choice primarily depends on the purpose of the system.

In verification mode, person states its identity, and the system tries to confirm if the claim is true or false. Such claim is usually made by stating username, inserting a smart card, or entering a pin code. Users of the system are aware of biometric system existence and they consciously participate in biometric recognition process. Therefore, biometric verification can be classified as a positive recognition method, where the main aim is to prevent multiple persons from using the same identity.

When operating in identification mode, biometric system performs one-to many comparison, it compares biometric data collected from a person with all identities stored in biometric database. The main purpose is to answer the following question: "Who am I?" Moreover, it is possible to perform biometric identification without

active participation of system users. Security applications, for example those deployed on the airports can especially benefit from this fact. Therefore, biometric identification can be classified as negative recognition method, as it is even possible to identify a subject who is trying to disclose his identity.

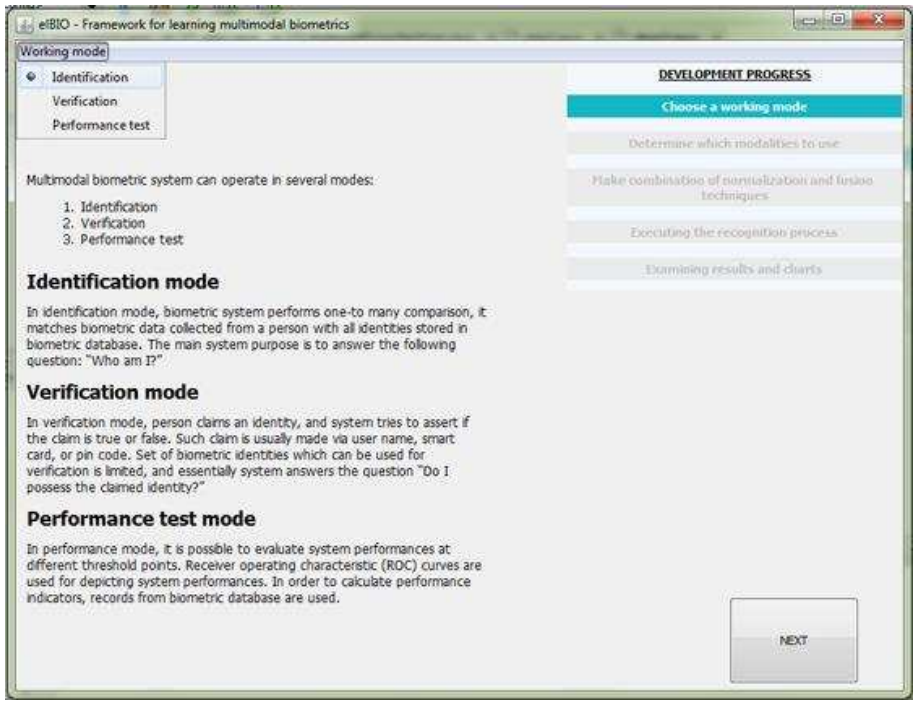

Figure 1: elBio working mode selection

As development progress panel in the top right corner of Figure 1 suggests, student needs to choose preferred working mode. It can easily be done by marking a radio button from the working mode menu. If in any moment student has doubts about correct working mode for desired system, they can consult displayed descriptions. By clicking on the button labeled "NEXT", selected working mode is memorized by the platform and it affects future behaviour of the elBio system.

4.2 Choosing biometric modalities

There are many different types of biometric modalities. In general, biometric modalities can be classified as physical or behavioral [Jain, Ross and Prabhakar, 2004]. A physical biometric modality is based primarily on anatomical or physiological characteristics rather than on learned behavior [IEEE, 2012]. An example for behavioral modality is signature, and a typical physical modality would be fingerprint. It is important to notice that some biometric modalities have both behavioral and physical characteristics. Human voice as a biometric modality has both of these characteristics.

At this point, elBio supports three different biometric modalities: face, fingerprint and voice. Fingerprint is the most commonly used biometric modality, and it allows more precise identification than face and human voice. On the other hand, face and voice are less-invasive modalities, and therefore have a broader range of applications. Moreover, non-intrusive biometric modalities are the only feasible choice for negative recognition applications such as background checks and forensic applications.

Depending on the purpose of desired multimodal biometric system, trainee can choose which modalities will be used. Also, elBio gives a possibility for fine tuning implemented unimodal biometric solutions. For example, this can be done by selecting various preprocessing, feature extraction and classification methods for each selected biometric modality.

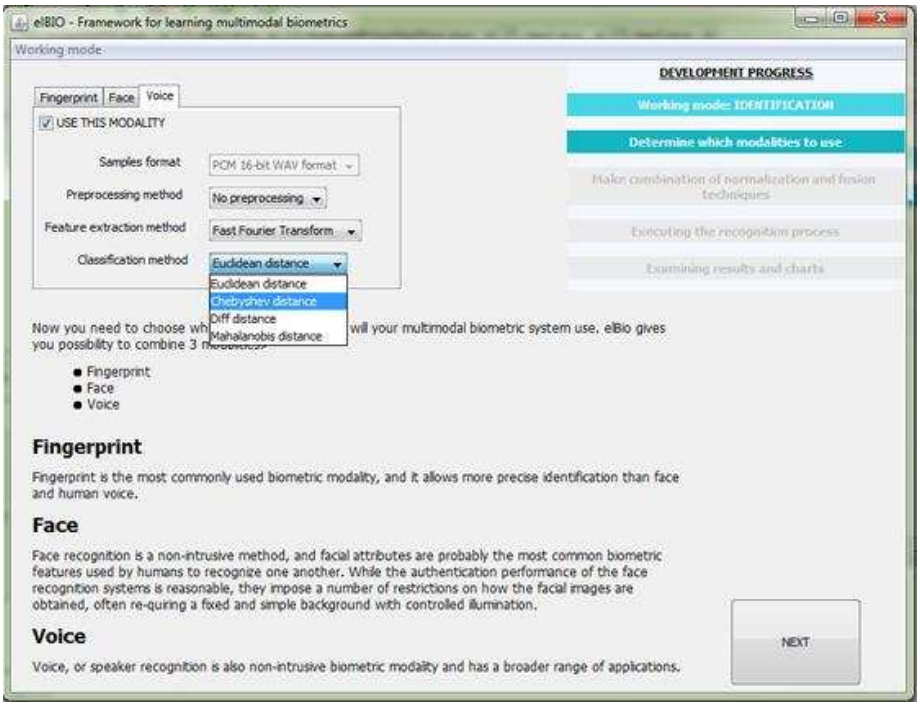

Figure 2: Fine tuning preferences for unimodal biometric solutions

Student can select desired modalities by marking appropriate checkboxes. A brief description of each modality is given underneath the selection panel and it can be used as a reference for system customization. Figure 2 presents modality selection interface.

4.3 Information fusion in multimodal biometrics

Multimodal biometric systems combine information collected from several various biometric modalities. With merging two or more biometric modalities, efficiency and precision of person recognition is enhanced. Thus, these systems become more

resistive to spoofing. Information from different sources can be fused on multiple levels:

- after feature extraction
- after matching
- after system decision

In transformation based fusion methods, matching scores are directly combined, without converting them to posteriori probabilities. In order to combine matching scores described by different measurement scales, it is necessary to normalize them before information fusion. Therefore, score normalization can be defined as transformation of scores generated by different matchers into a common domain [Jain, Nandakumar and Ross, 2005]. There are many different algorithms for normalization of matching scores, such as tanh, min-max, z-score or adaptive normalization.

Information fusion techniques combine matching scores from various biometric modalities into a single matching score [Alsaade, Ariyaeeinia, Malegaonkar and Pillay, 2009]. Some fusion techniques are straightforward, such as simple sum of scores, while others can be more complicated, and use additional information, such as user or biometric matcher data [Snelick, Uludag, Mink, Indovina and Jain, 2005].

elBio platform supports fusion on matching level, and currently several score transformation based fusion methods are implemented. It allows combining one normalization method with one of the fusion techniques. Figure 3 displays elBio's interface for selecting those methods.

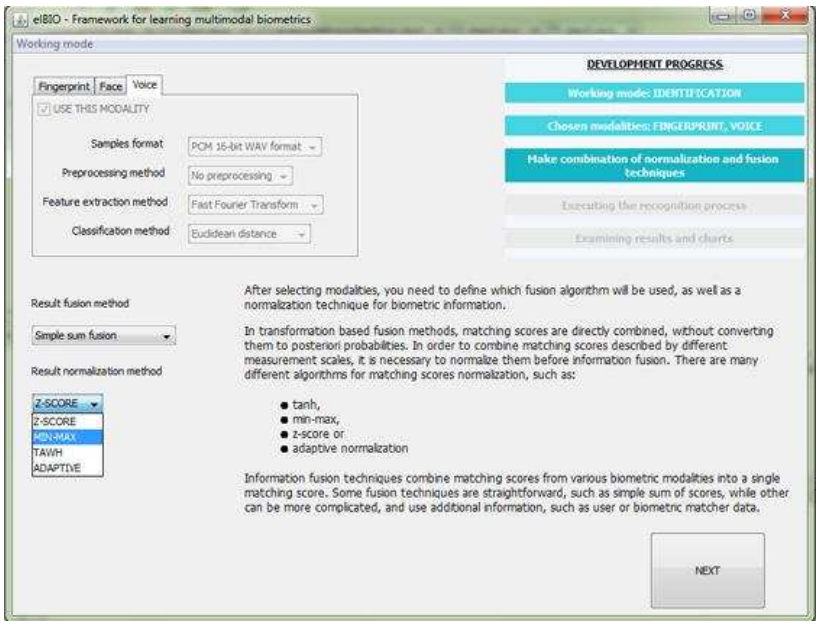

Figure 3: Selection of fusion and normalization algorithms

Since students are usually not familiar with concepts of biometric fusion and normalization, approach implemented in elBio platform allows easier familiarization with those concepts through succinct explanations. After choosing the combination, all prerequisites for a working multimodal biometric system are met. Student can check configured settings by using the development progress panel in the top right corner, and easily make a change by clicking on desired step. Finally, student can proceed to the testing phase.

4.4 Biometric system performance indicators

Algorithms used for biometric recognition are based on biometric characteristics. Biometric characteristics are representations of biometric data belonging to an individual. Use of biometric characteristics allows us to more easily apply pattern recognition algorithms, but also results in a loss of data because of the applied abstraction. Moreover, two samples of raw biometric data belonging to same person are never the same. There are several reasons for this fact, such as imperfect biometric data acquisition, biometric sensor noises, changes in biometric modalities due to aging, etc.

Estimations of biometric system errors are very important for system architects. Without them, it is impossible to conclude whether the system requirements were satisfied or not. Additionally, when trainees in the field of multimodal biometrics try out different combinations of biometric modalities, as well as normalization and fusion techniques, they need a framework in order to make a comparison between the effectiveness of different choices. Our idea was to provide visual presentation of performance indicators, in order to make learning process more interactive. Performance of the biometric system in verification mode is measured by two types of errors – False Match Rate (FMR) and False Non-Match Rate (FNMR). False Match Rate is the percentage of system users who claimed another person identity and were falsely accepted by the system. False Non-Match rate is the percentage of system users who made genuine identity claims, but where falsely rejected. These two errors are correlated, and both are dependent on biometric system threshold. If biometric system is using similarity measures, then by increasing system threshold we favor FNMR over FMR. Otherwise, if we decrease the system threshold, then false rejects will be fewer (FNMR), but the number of false accepts (FMR) will increase. elBio supports ROC (Receiver Operating Characteristics) curves. These curves depict system performances at various threshold settings, and by examining them it is possible to make an assessment of different FMR and FNMR combinations (Figure 4). It is important to notice that on Figure 5 Genuine Acceptance Rate (GAR) is used as performance indicator instead of FNMR. GAR is calculated as 1 – FNMR.

Aside from FMR and FNMR, for multimodal biometric system architects it is also important to have information about genuine and impostor matching scores distributions. Matching scores generated from pairs of biometric characteristics collected from the same person are called genuine matching scores, while matching scores generated from pairs of biometric characteristics belonging to different persons are called imposter scores. In order to visualize these distributions, elBio uses relative frequency histograms (Figure 4).

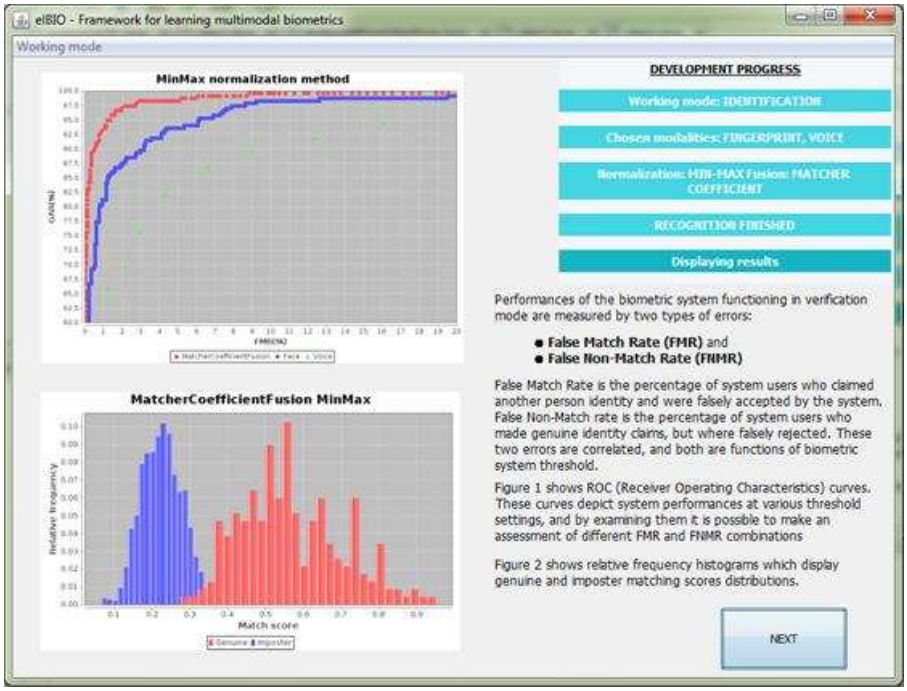

Figure 4: Results and performance indicators

5 Research study

In order to evaluate simulation based method of learning multimodal biometrics, we conducted a research, in which we compared traditional learning method and learning process based on elBio platform. The main objective of our study was to determine if elBio platform improves efficiency of learning biometrics process, as well as if it positively influences students' motivation and learning experience.

Research study was conducted in regular class settings without external disturbances. The research included 19 participants, students in the field of computer science, which were divided into two groups: control group, which took traditional lecturing and experimental group, which was using elBio platform as a learning tool. Participants' age ranged from twenty to twenty-three. Before start of the research, we held a short briefing in order to inform participants about the research protocol.

Traditional learning approach consisted of lecture with slide show presentation. Lecturer explained different steps of multimodal biometric system development, and students were free to ask questions. After the presentation, a brief discussion was held, in order to allow students to exchange their opinions and impressions. In the group which used support platform, each student had a computer with elBio installed at disposal. A lecturer was also present, but his role was to guide users through use of

support platform and to answer their eventual questions. Students were free to communicate and share their experiences.

Participants attended a lesson about biometrics technologies as a member of control or experimental group, which was randomly determined. After the lesson, students were asked to take a knowledge test regarding the biometrics technology material presented during the lesson. Knowledge test consisted of 16 questions and 6 practical problems in biometric system development. Additionally, upon completion of knowledge test, participants filled in a questionnaire which included six questions that related to motivational factors and 18 questions that referred to the learning experience. All questions were closed construction questions and they were based on principle of Likert scale [Likert, 1932].

In order to determine impact of elBio on learning efficiency and students' motivation and satisfaction with this learning approach, we compared the average results of knowledge tests for each group and also average values of students' responses on motivational questionnaire.

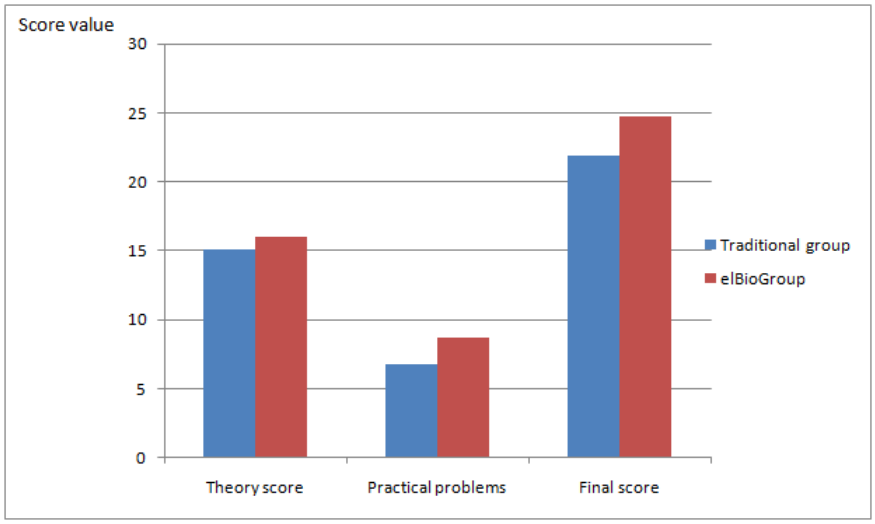

Figure 5: Average knowledge test results

Knowledge test results are presented in two groups, theoretical questions and practical problems. Each correct answer, given on theoretical question, was graded with 1 point, while proper solution of practical problem brought 2 points. Questions which have not been answered were not taken into account. Figure 5 presents average knowledge test results. Group that used elBio platform slightly outperformed traditional group on the knowledge test. Difference between these two groups was greater on practical problems than on theoretical questions.

In order to collect and analyze data about learning experience and motivation when using different teaching approaches, we used a Likert scale. Respondents expressed their satisfaction with the range of values from one to seven. On Figure 6, average answers on questions which refer to learning experience are presented. We

can see that the group that used elBio platform evaluated learning experience slightly better. Greater differences are present in students' experience that there is no theory and practice bond, and also that presented learning material is more complex and has too much information. Students which participated in elBio group evidently had stronger impression that there is a connection between theory and practice.

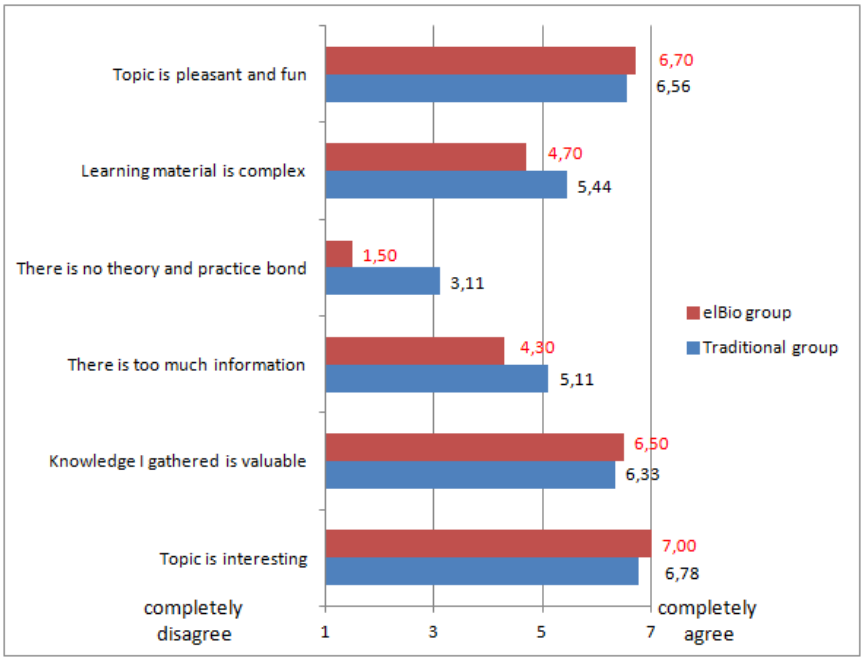

Figure 6: Average values for participants' learning experience

On the other hand, Figure 7 shows average level of agreement with statements regarding respondents' motivation when learning biometrics in one of tested ways. Presented results show that students are strongly motivated when using learning approach which includes elBio platform. However, not all motivating statements speak in favor of using support platform based approach in learning biometrics. For example, students reported that they could use more knowledge from other fields when learning in a traditional way.

We have conducted statistical analysis for each question found in the motivational questionnaire in order to determine effects of different learning approaches on motivation of our students. For the purpose of determining which learning approach has better influence on students' motivation,, we applied an independent samples t-test, with confidence interval of 90%. To test equality of sample variances we have used Lavene's Test for Equality of Variances. For t-test, grouping factor was whether subject used elBio platform or traditional methods, while the test variable was a quantitative measure of motivational effect per subject. We have found statistically significant difference between these two groups for the following statements: I can be creative; I learn dynamically; I can use different area

knowledge; I feel my capacities are fully used with this learning process; I could communicate with colleagues during learning process; There is no bond between theory and practice.

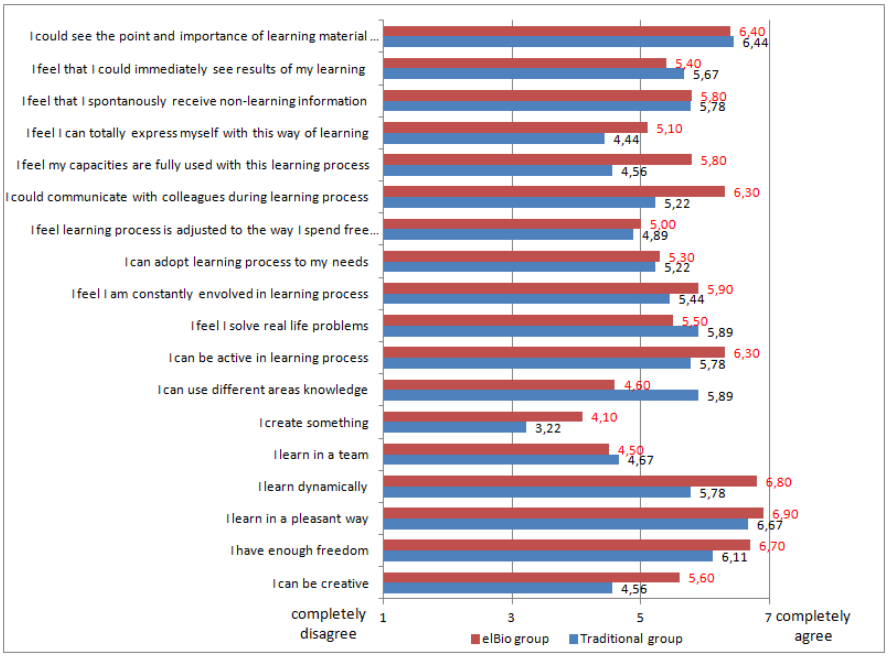

Figure 7: Average values for participants' learning motivation

6 Discussion

The main goal of this research was to examine whether implementing elBio platform for learning multimodal biometrics as a teaching tool could improve students' motivation and interest in biometrics technologies. More accurately, we tried to find out whether interactive nature of elBio platform and its focus towards creating a specific multimodal biometric system, overcomes mentioned issues of a traditional learning approach.

In motivational questionnaire, students have stated that it was easier to grasp connection between theory and practice by using the platform. A possible explanation would be that learning approach based on support framework offers students a better insight into multimodal system development process. Students can try out different settings for each system development step, and in the end they can see results of decisions made earlier. In that way, it is possible for students to apply newly acquired theoretical concepts, and also to see practical consequences of their decisions. In contrast, when using traditional learning approach, participants were not able to practically apply their knowledge. Test results reinforce these conclusions, as group

that used elBio platform has had larger average scores on practical problems given in the test.

According to analyzed data, the usage of elBio platform allowed students to be more creative. During the learning process, students could try different combinations of biometric modalities, preprocessing, classification, normalization and fusion techniques. They could imagine different scenarios in which biometric authentication was needed, and afterwards they could try to create a multimodal biometric system specifically tailored for such use. On the contrary, members of group that learned by using traditional approach were not given such an opportunity, so they were not able to fully express their creativity.

Analysis of the responses revealed that study participants felt that traditional learning approach had not used their full capacities, while members of the other group felt more engaged. Probable reason for this differentiation is that when using traditional learning method, participants have a more passive role. Aside from listening, they can only sometimes ask questions and eventually take a part in the discussion. On the other side, students which used elBio platform were able to participate more actively. While developing their multimodal biometric system, they needed to make various decisions for which their full attention was needed. Additionally, constant engagement and decision making results in a more dynamic learning approach. Questionnaire results confirm this statement.

It should be noted that considerable difference between the two groups was found for question "I could communicate with colleagues during learning process." Students which used elBio platform had higher average score on this question than their colleagues which learned using the traditional approach. One of the reasons for such difference is that study participants from elBio group have felt more freely to discuss problems with their nearby colleagues due to the more informal learning environment. In traditional learning approach, discussion was supposed to come after the presentation, and some of the participants felt uneasy to openly state their opinions, or ask question before all of their colleagues.

However, as we stated earlier, not all of motivating statements speak in favor of using support platform based approach in learning biometrics. Members of the traditional learning method had higher average level of agreement with statement "I can use different area knowledge". A possible explanation would be that learning platform places some limitation on students' activities. Although they were able to express their creativity, their attention was focused on topics and areas covered by the platform. Therefore, negative effect of support platform is the neglection of other uncovered, but potentially important aspects of multimodal biometrics system development.

Due to the small number of survey participants, we were not able to determine if differences for other statements in the motivational questionnaire were statistically significant. Nevertheless, it is important to mention that average values for most of those statements were higher for group which used elBio support platform for learning biometrics.

7 Conclusions

In the future, multimodal biometric systems will be widely used in various areas of our lives. As a result, engineers with deep understanding of biometric technologies are going to be in high demand on the market. During our research on project "Multimodal biometry in identity management", we have realized the importance of promoting biometrics technologies and training new biometric engineers. Because biometrics is a cutting edge technology, with a specific with many domain specific definitions, traditional learning approach proved to have some shortcomings. As our research efforts in this area provided no software which could make learning of multimodal biometrics easier, we have decided to invest efforts into developing a support platform for learning multimodal biometrics.

We have detected three key issues connected with the traditional concept of learning. Proposed learning approach based on usage of support tool for learning multimodal biometrics should provide a solution for identified issues. In order to solve the issue of interactive content, elBio guides trainee through a series of interactive steps in form of a tutorial. It is possible to simulate biometrics verification and identification processes and try out different combinations of normalization and fusion techniques. By trying out different system settings, students can apply their theoretical knowledge to solve real world, practical problems. Learning approach based on the support tool offers more control over the learning process, allowing users to adapt learning tempo to according to their preferences. Thus the third issue and final issue has been considered.

Research study was conducted among students in the field of computer science, and included 19 participants. Results of research study speak in favor of using elBio support platform as a teaching tool. According to survey results, students who used support platform were more motivated, and also more satisfied with the learning experience. However, our support platform has some shortcomings, such as neglection of uncovered but potentially important aspects of multimodal biometrics system development. Some of the fusion techniques for multimodal biometrics were not included in the framework. Also, some of the visualization techniques, including cumulative match characteristics for measuring identification performance and zoo plots for showing individual user performance. These shortcomings should be addressed in future versions of elBio support platform.

Positive responses encouraged us to continue development of elBio. As it still has limited functionalities, we plan to integrate more open source solutions and make learning process more interactive. Also, assessment of whether elBio is better technique for learning about multimodal biometrics could be done by performing qualitative analysis of user opinions, for example using some of the techniques described in [Miles and Huberman, 1994]. Our long term goal is to make presented support tool an open source project, and to encourage contributions from other developers. We expect that it will definitely improve elBio support tool and make it more useful for future multimodal biometric system developers.

Acknowledgements

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