

## Research premises and importance of the research topic

Biometrics is a scientific discipline comprising methods for user recognition based on unique and measurable physical, biological, or/and behavioral human characteristics. Biometric recognition techniques are used as basic security mechanisms deployed in access control applications at secure buildings, airports or border crossings, as means for recording employee attendance, or as a source of consumer information in intelligent advertisement applications.

The use of biometrics has recently expanded to other application areas as well. Biometric recognition techniques are being increasingly deployed in ambient intelligence environments, where they serve as means for detecting and recognizing the presence of particular users. In these environments, the facial modality is the preferred choice for the implementation of the biometric recognition procedure, mainly due to its desirable characteristics, such as the capability of recognition at a distance, the high degree of user acceptance and last but not least due to the cost-efficiency of the technology. Unfortunately, the existing (face) recognition techniques struggle with their performance in uncontrolled environments, such as those featured in ambient intelligent applications. In these applications, the techniques have to cope successfully with variations in the external lighting conditions, variations in pose and facial expression, low resolution imagery and of course ageing of its user base. All of these factors impose a great challenge to the biometric technology and require to be solved.

Obviously, the difficulties encountered when deploying face recognition technology in ambient intelligence environments greatly overlap with the research problems currently tackled by the face recognition community. Here we have recently seen a shift from the research of isolated problems related to illumination, pose, facial expression or ageing to the research of the interaction of different sources of face image variability and its impact on the recognition performance. Hence, the current research trends in the area of face recognition are focusing on “real-life” problems, where the different sources of face image variability are present at once.

The exceptional topicality of the area of face recognition in conjunction with ambient intelligence environments is not evidenced solely by the ever increasing number of R&D centers devoting their attention to this area, but also by the interest of influential institutions, such as the European commission, which supported the idea of ambient intelligence environments with the establishment of the advisory group IS-TAG. The group composed a report entitled “Scenarios for Ambient Intelligence in 2010”, which identifies ambient intelligence applications as one of the priority research fields in the EU. The popularity and potential of both face recognition technology and ambient intelligence applications offers the opportunity for participating in further EU research projects and is important from the perspective of research impact as well.

## Problem presentation

Although several studies and much available literature has addressed the problem of automatic face recognition, implementing a comprehensive and most of all robust face-recognition system capable of operating in ambient intelligence environments, is by no means a trivial task. As part of the applied post-doctoral project “**B**iometric face recognition in **a**mbient intelligence environments (BAMBI)” we will focus on the research of robust techniques that allow for the development of such a system and are based on the following facts:

1. The number of users that need to be recognized robustly in ambient intelligence environments is usually limited.
2. A large number of training images is available for each user, which enables the deployment of incremental training techniques.
3. The variability of the face images is enormous and is commonly a consequence of several factors (e.g., illumination, pose, expression and ageing) and their interaction.

A number of problems will be tackled:

1. The need for real-time operation.
2. Robust detection of people and faces in the video frames (or images) in the presence of variable external conditions.
3. Robust normalization of faces.
4. The construction of invariant user models that allow for their incremental updating

### **Research goals**

The first (research) goal of the post-doctoral project involves developing algorithms for efficient face detection in the presence of extreme pose and lighting variations and novel methods for face recognition capable of ensuring stable recognition performance in the presence of several sources of face image variability. As part of the of the first research goal we will strive to develop a robust real-time face detection procedure surpassing the detection capabilities of the established Viola Jones object detector from the perspective of performance as well as robustness. Similarly, as part of the second research goal we will try to find novel techniques for robust face recognition in the most difficult scenarios, where interactions between the different sources of face image variability affect the appearance of the users face.

The second (applied) goal of the post-doctoral project involves developing a prototype system for biometric face recognition deployable in ambient intelligence environments. As part of the applied research goal, we will devote our attention to the adaptation of the developed procedures more towards the characteristics of ambient intelligence environments. Hence, we will implement the system accordance with the client-server model, which allows for central processing of the image data and the use of several input sensors (i.e., cameras).

### **Anticipated original results and their potential impact**

We expect the planned research in face recognition in uncontrolled and unconstrained environments will lead to important new discoveries in the global standard and will pave the way for the introduction of new techniques in biometric face recognition systems for ambient intelligence environments in practice.

The expected results of the project comprise novel robust procedures for face detection and recognition and a prototype face recognition system deployable in ambient intelligence environments. Developing such a system offers an opportunity to develop our own biometric technology and the know-how connected with it, which will be indispensable in introducing

biometric systems for processing data from the new biometric passports. Thus, the conducted research will enable us to participate actively in potential future projects related to biometric technology and security mechanisms for border control.

The originality of the developed solutions will be demonstrated through scientific publications in leading peer-reviewed international journals, where we will present novel approaches for the detection and normalization of faces, robust face recognition in uncontrolled conditions and incremental updating of user models. The results of the research will also be presented at high profile international conferences and workshops. Furthermore, we believe that the topic of the post-doctoral project will enable us to strengthen our ties with other research groups working in the fields of biometric face recognition and ambient intelligence.

## **Methodology**

In our research work we will rely on existing implementations of known computer vision, pattern recognition and biometric algorithms featured in open source libraries such as OpenCV or Torch, as well as our own toolboxes such as the INFace (Illumination Normalization Techniques for Face Recognition) Matlab toolbox, which has been made publicly available and has been downloaded more than 1000 times over the last year from its repositories at the Laboratory of Artificial Perceptions, Systems and Cybernetics and Matlab Central.

We will assess all developed techniques on challenging databases such as the “Labeled Face in the Wild”, “Public Figures” or “Big Brother” databases, which feature face images captured in uncontrolled environments. A special focus will be given on the last of the three listed databases, as it is designed for developing face recognition systems for intelligent homes, which in general exhibit great similarities (in terms of image characteristics) to ambient intelligence environments. If needed, we will augment the database with our own image data, which will be annotated with existing semi-automatic annotating tools that we have developed as part of our past research.

Our research will proceed from the following algorithms, which we will strive to improve through new and original ideas:

1. Face detection and localization procedures relying on advanced correlation filters, which exhibit desirable properties such as real time capabilities, mathematical simplicity and short training times,
2. Geometrical normalization procedures relying on Active Appearance Models (AAMs) and methods for their modification due to ageing effects,
3. Photometric normalization procedures based on the RETINEX theory,
4. Procedures for robust feature extraction (e.g., Gabor filters, Local Binary Patterns, ...),
5. Template modeling methods based on graphical models,
6. Probabilistic techniques for template modification (e.g., tied factor analysis) and
7. Existing classification techniques.

In the final stage of the project we will validate all developed procedures within the prototype recognition system, which we plan to set up at the research organization, where the post-doctoral project will be conducted.

### **Project organization and feasibility**

The post-doctoral project BAMBI will be conducted in three phases that comprise:

Phase 1: Research and development of a robust face detector and accompanying normalization procedures for normalizing the detected facial area

Phase 2: Research and development of robust feature extraction procedures, modeling techniques and template modification approaches

Phase 3: Integration of the developed procedures into the prototype recognition system

In the second phase of the project application a detailed time-plan will be constructed, which will define the project activities, milestones, project deliverables, and the critical path.

In carrying out this ambitiously conceived project, we will make use of our past experience in developing image technologies, pattern recognition techniques and biometric systems. The work within the proposed post-doctoral project will also represent a continuation of other research work we have conducted by within EU and Slovenian sponsored programs and projects such as the CRP project AvID, the Metrology and Biometric Systems research program, the EU IST projects BIOSECURE and HIDE, or the COST Action 2101 Biometrics for Identity Documents and Smart Cards. As part of work on these past projects, we have also acquired all of the necessary equipment and several biometric databases, which will provide the project infrastructure.