Distributed Face Recognition: A Multi-Agent Approach

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Summary

In this paper we present an application of agent technology to the problem of face recognition. With a new composite model consisting of multiple layers, the system can achieve high performance in terms of robustness and recognition in complex visual environmental conditions. The robustness of the complex face recognition system is enhanced due to integration with agent based paradigm, with more than 95% accuracy achieved under illumination, pose and expression variations of faces in images with multiple faces, and background objects. The results of preliminary findings are promising, suggesting further investigations in intelligent agent methodology for facial biometrics using fusion of face, gait, gesture, and voice biometric traits to person identity recognition problem in distributed scenarios such as video surveillance, health informatics, and crime investigation applications.

Key words:
Face recognition, multi agent, scale, pose invariance.

Introduction

In recent years applications of biometric technologies are not just limited to high security border control and national security scenarios, but in day-day civilian and e-commerce applications [1]. Many different biometric traits are available for person recognition such as fingerprint, face, voice, gait, retina, iris, hand geometry and vein patterns. However, recognition based on any one of these modalities may not be sufficiently robust or else may not be acceptable to a particular user group or in a particular situation or instance.
Current approaches to the use of single biometrics in person identity recognition are therefore limited, principally because no single biometric is generally considered both sufficiently accurate and user-acceptable for universal application. Multimodal biometrics can provide more robust solutions to security and convenience requirements of many applications such as video surveillance, crime investigation, and health informatics scenarios, where there is a need to recognize the identity from insufficient biometric sensor data.
For example in face recognition systems in video surveillance scenarios, low resolution images in cluttered background, difficulty to obtain frontal face images, bad lighting, occlusions, pose and expression variations, and multiple persons in the scenes, are typical challenges which the face recognition algorithms are confronted with. Moreover, for distributed implementations, the different stages of face recognition, such as the acquisition stage of capturing face biometric information, the feature extraction stage, the template acquisition and classification stage are spatially and functionally distributed, with complex hierarchies of security levels and interacting user/provider requirements. The face recognition systems deployed in such distributed environments require that the system is adaptive and flexible in configuration, for which an approach based on innovative multi-agent based paradigm [2-4] can be very promising.
The paper is organized as follows. Section 2 reviews previous approaches in related agent based computing paradigm, and Section 3 discusses the proposed system architecture, with highlighting its three-layer structural model and three-layer functional model. Section 4 reports the experimental results, with some conclusions presented in Section 5.

2. Agent based facial biometrics

In considering the use of facial biometrics in another scenario for example, a realistic distributed civilian environment, such as a public system for regulated access to healthcare records, it is clear that there are several inter-related sources of variability which are likely to affect the required performance of the authentication

Manuscript received August 5, 2006.
Manuscript revised August 25, 2006.

system. These sources include, for example, environmental conditions, users' physiological/behavioural characteristics, users' preferences, variability of the communication channels, and so on. Thus, there is a clear requirement for the system to be able to adapt to user needs and conditions and, especially, to be able to determine and maintain an acceptable balance between confidence and convenience for its users through negotiations between information users and providers.

The use of intelligent agent methodology allows efficient management of complexity introduced by the use of facial biometrics for remote access. Intelligent autonomous agents [3], and multi-agent systems form a vibrant and rapidly expanding research field [5]. Agents can be defined as computer sub-systems that interact with some environment, and are capable of autonomous action. In addition they are flexible in responding to their environment, pro-active in exploiting opportunities and seeking goals and "social" in their interactions with other agents where appropriate. In addition they may have other valuable properties such as adaptability or mobility.

In this paper we report the proof of concept experiments based on innovative multi-agent architecture to solve the problem of distributed face recognition in complex environments. The architecture is based on adapting the MARSE, a multi-agent systems framework, proposed by Intelligent Systems Group at the University of Canberra [2] for distributed face recognition task. The architecture consists of a fusion of multi-layered structural and functional models in a network-oriented distributed environment. The system uses agent oriented implementation of facial biometric modality to check and verify identity, The technique used allows robustness to environmental and person-specific variations in which a system is accessed, and includes several features such as significance, confidentiality and cost of data, capture environment and recognition success rate histories of individual biometric traits for the person.

3. System Architecture

The multi-layer structural and functional model can be viewed in two ways: one at structural level, and the other at the functional or operational level, as shown in Figure 1. The four-layers of the system at *structural* level are:

- The *interface* layer: A communication channel between the input/output device and the application server.

- The *central controller* layer: To control all inner biometric recognition schemes as well as implementing an intelligent detection strategy.

- The *external assistant* layer: Includes a group of agents to help implementation of feature extraction schemes.

- The *remote application* layer: An outer application part of the system which is used for face matching by connecting remote legacy databases consisting of biometric templates.

At *functional* level , it consist of three layers:

- A *central agent host* layer implementing an intelligent detection scheme on a single PC.

- A *neighboring agent host* layer implementing a feature extraction scheme in for parallel computing environment.

- A *remote agent host* layer implementing a remote face-matching scheme in a distributed computing environment.

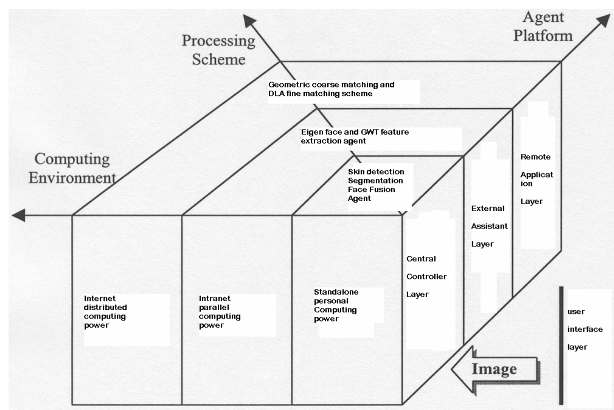


Figure 1 : Multiagent based face biometric system architecture

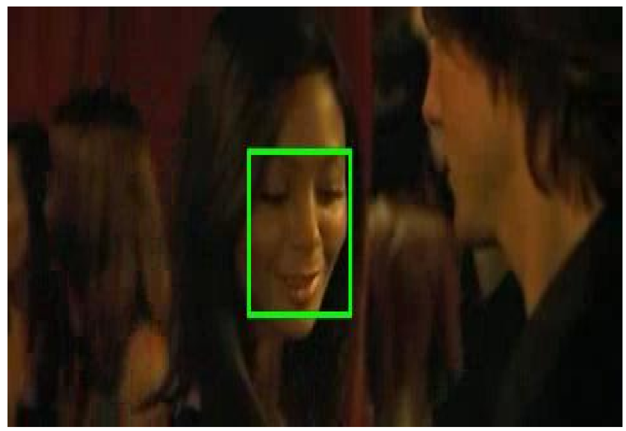
The details of each layer in the structural level can be summarized as:

- *The interface layer* – This layer allows an easy access to the system by establishing a point-to-point input/output layer explicitly connecting the input/output device and the application server. All recognition schemes are hidden from the end user. A user interface is used to accept the input image and return recognition results.
- *The central controller layer* – This layer is the main part of the whole system and connects

all sub-systems. A novel face detection scheme based on fusion of multiple colour spaces is implemented in this layer. Three stages of face detection that is colour segmentation, the skin-region detection, and face fusion is done by three agents in this layer*:*

- *Skin segmentation agent* - The facial region is localized by this agent based on statistical skin colour distribution and thresholding. Then the knowledge about facial patterns (distribution of non-skin sub-regions) is used to determine instances of face within such regions. The agent uses morphological operators to divide different convex objects, removing regions that are too small, and recovering regions' sizes while keeping the same topological structure.
- *Skin region detection agent :* This agent localizes the face region by matching the skin regions with a template, and eliminates those skin regions which do not correspond to face region such as hands.
- *Face Fusion agent*: This agent performs fusion of face segmentation and face region detector based on multiple colour spaces such hue-saturation(HSV) colour space, chrominance-luminance colour space (YCrCb) colour space, and RGB colour space.Use of multiple colour spaces allowed a face detection accuracy of more than 90% under complex visual background conditions as shown in Figure 2.

- *The external assistant layer:* The external assistant layer extracts features from face images, including both local and global features. First, global features are extracted by principal component analysis (PCA) or Eigen-face approach, while local features are obtained by active appearance model (AAM) and Gabor wavelet transform (GWT) [8-11]. Extracting global and local features is computational intensive and hence we use a group of external computation agents and adopt the "Divide and Conquer" strategy in this layer. Figure 3 shows the extraction of global features based on Eigen-face approach.
- *The remote application layer*: Remote face matching scheme is implemented in this layer. Based on the fact that large image databases with different formats might be located in different places over the network, it makes more sense if the agent moves to the remote data source for searching and matching, rather than transferring large volumes of data over the network for processing. In this layer, we explicitly create a matching agent, initializing it with matching algorithms and dispatching it to the Internet. Upon reaching a new host, the matching agent interacts with remote agents and communicates with the backend databases for searching and matching.



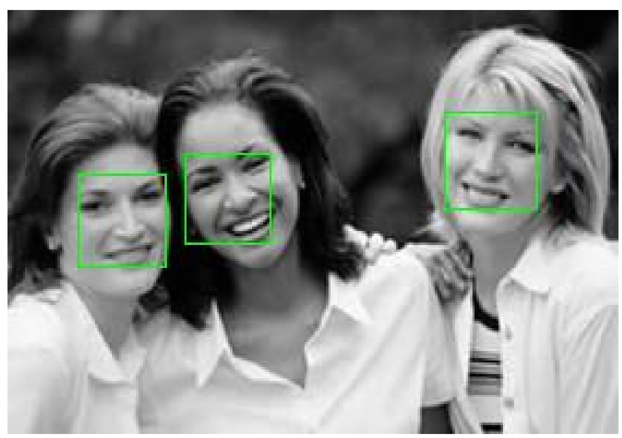


Fig. 2 Face detection in a complex visual background

A two-step-matching scheme is performed: geometric-based coarse matching and dynamic-link architecture based accurate matching [12]. Geometric, feature-based face recognition is among the earlier algorithms proposed [10]. As the image database becomes larger, however, it turned out to be impossible to perform accurate recognition by simply using this scheme. However, we embed this algorithm into our proposed matching agent as an effective pre-filtering for the second-step for accurate matching. In the second step, the overall geometrical configuration of the face features is described with a vector of numerical data, representing the position and size of the main facial features, e.g. eyes, nose and mouth, and supplemented by the shape of the face outline [11].

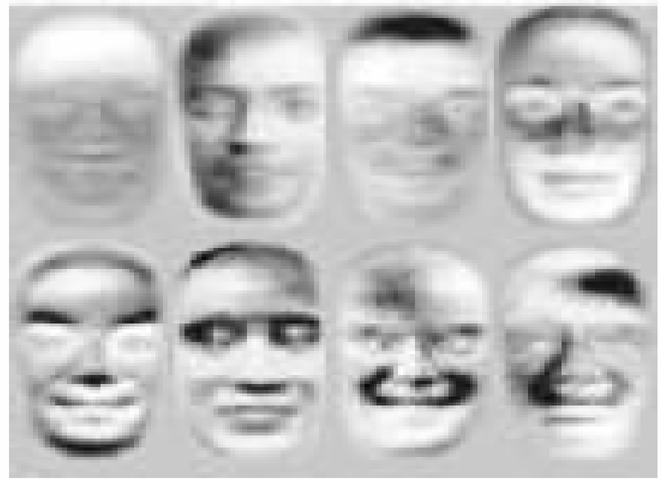


Figure 3: Extraction of global features with Eigen-face approach

For both steps, a nearest neighbour-hood classifier is used for the proof of concept experiments, and a Hidden Markov Model (HMM) classifier would have given better classification performance. Its performance is a function of the number of classes to be discriminated (people to be recognized) and of the number of examples per class.

5. Face Recognition experiments

To implement and evaluate the system performance, we used the IBM ABLE environment [8,9]. ABLE is a Java framework, component library, and productivity tool kit for building intelligent agents using machine learning and reasoning. We conducted experiments at different levels of framework. Three sets of experiments are conducted: Face Detection Experiments (FDE) in the layer I, Feature Extraction Experiments (FEE) in the layer II, and remote Face-matching Experiments (FME) in the layer III. The FDE Test aims at evaluating the algorithm's robustness in the proposed detection agents under different visual environment variations . Then the FEE test evaluates the accuracy with which features are extracted and further used by remote face matching agent. Finally, the FME test examines the correctness and effectiveness of remote face matching scheme in a distributed environment.
In order to obtain a stable colour segmentation with noisy face images, more than 1000 face images with variation in pose and illumination and different types

of skin are chosen as the training samples for the colour segmentation agent. More than 100 face images were used for the FEE test. The experimental results illustrated in Table 1 show that the improvements achieved for FME tests in terms of robustness to the variations in pose, lighting, multiple faces, moderate tilt of faces and partial occlusion.

6. Conclusions

Facial biometrics provide a practically viable approach for overcoming the performance and user acceptability barriers to the widespread adoption of biometric systems. However, it is essential that the resulting complexities are managed in a seamless and effective way. The paper introduces a multi agent systems approach for distributed face recognition problem. The combination of powerful feature extraction algorithms with multi-layer structural and functional model allows higher face recognition accuracy even under adverse environmental conditions. In contrast to current face recognition models, which suffer from slow performance and platform dependence, the proposed multi-layered system model with several improved algorithms has been tested through experiments, demonstrating its feasibility and effectiveness. Coupled with other supporting schemes, the system is potentially useful in a wide range of distributed face recognition services such as remote video surveillance, health informatics and criminal identity verification.

Visual Environmental Conditions	FDE-I	FDE-II	FEE-I	FEE-II	FDE-II +FEE-II
Unevenness of lighting	84.56	86.57	89.79	91.46	96.23
Multiple faces in the scene	85.55	88.48	91.16	90.57	93.47
Moderate tilt of faces	87.59	90.29	92.85	89.66	94.18
Pose and expression var.	89.48	89.44	91.11	92.38	91.33

Table 1: Face Recognition accuracy (%): FDE-I :Face detection based on single colour space; FDE-II: Face detection based on fusion of colour spaces; E-I: feature extraction based on global PCA features; FEE-II based on fusion of PCA+GWT

7. References

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