Face Recognition Based on Recursive Bayesian Fusion of Multiple Signals and Results from Expert Classifier Sets

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Abstract. We report on a system for person identification based on face images. The system uses sequences of visual wavelength intensity and thermal image pairs as input and carries out classification with a set of expert classifiers (such as ANN or SVM) for each input signal separately. The decisions of the classifiers are integrated both over the two signals and over time as new image pairs arrive, using stochastic recursive inference based on Bayes formula. Our experimental results indicate that both recognition and rejection rates are higher than those for the expert classifiers alone.

1 Introduction

Image-based face recognition systems have reached a high level of performance and technical sophistication, and several commercial systems have appeared on the market. However, benchmark tests indicate that there are still unsolved problems [1]. Some of these problems are:

- Robustness against *illumination-, head pose-, and distance-to-face changes* is still not high.
- Robustness against change in *facial expression* is still difficult to realize.
- Robustness against simple *forgeries*, such as presenting photos instead of real faces to the system, is still difficult to achieve.
- Achieving *very high recognition rates* for registered faces and *very high rejection rates* for unregistered faces is still unaccomplished.

Partly because of these problems, the conviction of many researchers in the field that face recognition should be viewed as just one of several components of a comprehensive biometric person identification system is gaining support.[2, 3] With such systems it may not be necessary to aim at close-to-perfect face identification rates. Nonetheless, we take the stance that it is worth the effort to gain a deeper understanding of face recognition methodologies and to further develop the capabilities of face identification technology.

In this paper we present an approach to face identification which uses a richer input data representation than is usually used. Although we have no intention

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to provide solutions for the facial expression problem in this paper, we intend to show that a richer input data representation in conjunction with an appropriate signal and decision fusion algorithm can be effective for overcoming the high recognition and rejection rates problem. Our method also provides (at least partial) solutions for some of the other problems. In Section 2 we discuss the utility of a specific richer input data representation, in Section 3 we introduce our face identification approach in more detail, and in Section 4 we present experimental results in order to demonstrate the effectiveness of the proposed method. The presented face identification system can be thought of as an extension of an earlier system we described in [4].

2 Face Recognition Based on Multiple Signals

In recent years there have been various efforts to improve the recognition rates of face recognition systems; for example, multiple classifier systems have been applied [5] or methods for information fusion have been explored [6]. These methods were shown to raise the recognition rate, but not enough to achieve reliable face recognition in many application areas. As an extension of these ideas, we propose to combine the usual *light intensity* face images with *thermal* images, and in addition use image sequences instead of single still images for recognition. Furthermore, we suggest to utilize range data at the preprocessing stage. The motivation for this proposal is as follows:

In [7] it was shown that thermal facial images can be used for face recognition, although the recognition rate was not very high. Furthermore, a good deal of the visual information in thermal images seems to be complementary to that of visual spectrum images. Using thermal imagery also helps alleviate the problem of changing facial appearance due to changes of illumination direction. Thermal imagery also can be useful for making face recognition more robust against forgeries, and it enables the system to function in darkness, although at reduced reliability.

Using image sequences instead of single still images provides more information mainly due to head pose variation, which increases the statistical confidence of recognition results. The idea of using faces in motion for face recognition has been discussed in [8], but the number of concrete studies is still limited.

The advantage of using range data is due to the fact that range data allow us to determine the apparent size and position of face image frames within scene images more accurately.

In order to capture this kind of input data we use an image acquisition system which consists of a camera that is sensitive in the far infrared wavelength band for capturing thermal image sequences and a stereo camera which takes color image sequences in the visible spectrum of the scene. The stereo camera provides color and light intensity images together with range data. The two cameras have parallel lines-of-sight in the same direction. Thermal images and visual spectrum images are synchronized and mutually registered. Image registration is carried out by using the range data from the stereo camera system. Face images are cut