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Multispectral Face Recognition

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15.1 Introduction

Face recognition technology has steadily progressed from adequately handling only well-controlled imagery to tackling increasingly more realistic conditions. This progression has seen the introduction of nuisance factors such as pose, illumination, occlusion and facial expression as integral components of the standard face recognition problem. A large body of research has accrued, aimed at coping with increased levels of image variability while maintaining high recognition performance. Variation in level and nature of illumination is among the most insidious problems for recognition algorithms, and thus a considerable portion of that research centers around it. Among other techniques, the use of thermal infrared imagery, by itself or in combination with other modalities, has been proposed as an alternative means of handling the problem of variable illumination conditions.

Variation in illumination conditions between enrollment and testing is one of the major problems for visible-spectrum-based face recognition [2, 26]. Since the radiance sensed by a visible camera at a given image location is proportional to the product of object albedo and incident light, changes in illumination can have dramatic effects on object appearance. In terms of faces, this makes modeling the distribution of appearances of a single person under multiple lighting conditions very difficult. Cast shadows, specularities and other non-Lambertian phenomena make the problem even harder. Multiple techniques have been developed to handle this issue [3, 31, 16, 26, 11], all of which improve recognition performance by explicitly taking into account the effect of illumination on facial appearance. An alternative route taken by some researchers is to explore the potential of thermal infrared imagery for face recognition. The primary advantage of this imaging modality is that changes in ambient illumination have little or no influence on facial appearance. Thus, instead of incorporating the large variability in appearance caused by lighting variation into a model, a new imaging modality is chosen so that such variability is simply not present.
Another critical shortcoming of visible cameras is that as the level of illumination decreases, the signal to noise ratio rises quickly, and recognition becomes impossible. Compared to the human eye, standard visible cameras are not very sensitive, which means that even at illumination levels for which a human can easily discern and recognize faces, automatic recognition is not feasible. Of course, as the light level decreases further into darkness, automatic processing remains impossible. This issue has been addressed recently by using both thermal infrared and intensified near-infrared (NIR) imagery, alone or in combination.

While thermal imagery provides us with the advantages of illumination invariance and no-light operation, it is not without shortcomings. Of particular importance is the fact that thermal emissions from the face are dependent on ambient temperature and wind conditions, as well as on metabolic activity of the subject. Additionally, the fact that the lenses of most glasses are opaque in the thermal infrared means that a large portion of the population have partial occlusions in the infrared images of their face. This is an important issue that must be addressed by any deployable thermal face recognition system. Fortunately, most of the situations that hamper recognition performance with thermal imagery are not a problem for visible imagery, and vice-versa. For this reason, systems using a combination of both modalities have proved time and again to be superior to those using either modality separately.

In Section 15.2, we review the nature of thermal infrared imagery of the human face. This provides motivation for the use of such imagery in biometric applications, and also indicates some of the strengths and weaknesses of the modality. The rest of the chapter is structured to reflect the nature of the recognition task, and the historical development of the field. We progress through same-session recognition experiments (training and testing face images acquired in the same session), where we mention the earliest and simplest experimental setups used to validate the use of thermal imagery for biometrics, to more complex and realistic scenarios where we explore the effect of time passage, unconstrained outdoor illumination and low light levels. Most of the research highlighted in this chapter is due to work at Equinox Corporation, although we mention the efforts of other groups.

### 15.2 Imaging Modalities

Before discussing specifics of multispectral face recognition, we should briefly review the nature of the imagery in each band of the spectrum. Figure 15.1 shows wavelengths from just below 0.4 microns up to 14 microns. The human eye is sensitive to radiation roughly in the range between 0.4 and 0.7 microns, depending on individual variation. Blue colors are perceived toward the low end of that range, while reds are near the top. Imagery captured in this range is purely reflective, meaning that the photons sensed by the focal plane array originate at a light source, bounce off the target object and into the