Multi-parameter illumination and image processing in the W-band for concealed object detection

Vrije Universiteit Brussel

In recent years the research field of mm waves, the spectral band between 30 and 300 GHz has expanded in security and biomedical applications, because mm-waves yield a convenient compromise between acceptable resolution and sufficient penetration depth through a variety of materials, non-transparent in the visible. E.g. mm waves penetrate clothing to image concealed weapons, but also allow skin cancer detection and skin wound healing assessment. In indoor applications (the biggest market in any sense) the temperature contrast between objects under investigation, the body and the background of the scene (e.g. walls of a room) is too low for making high contrast imaging in a reasonable exposure time. For several years the LAMI research group at ETRO-VUB has been looking for adequate illumination techniques for achieving significant image contrast enhancement and additionally increasing the information content. The main issues to solve is firstly to understand typical mm-wave imaging artifacts such as glint, Gibbs ringing, deterministic and stochastic interference noise due to the coherent illumination technique, secondly to reduce their impact in object misinterpretation and thirdly to extract more information content from these images than possible with passive imaging systems by applying advanced image processing algorithms.

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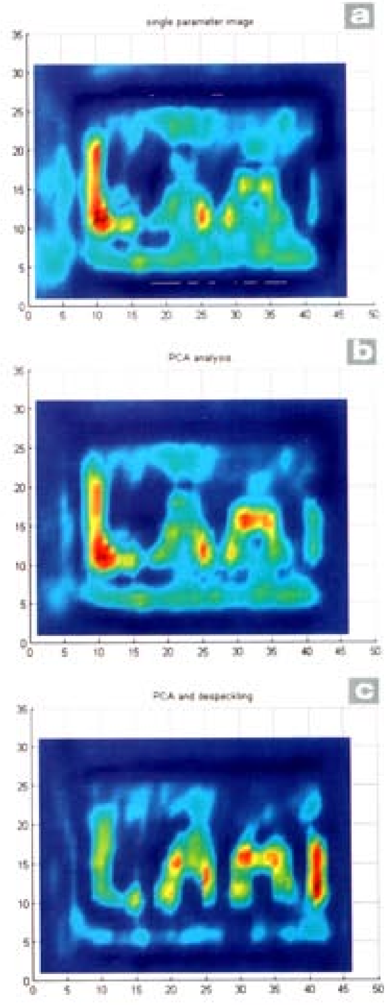
The first years of the research have been devoted to the theoretical analysis of the aforementioned typical image noise and artifacts due to the coherent illumination in a quasi-optical mm wave imaging system. By using the Fraunhofer approximation, one could perform this analysis in the framework of the spatial frequency domain, well known in optics, but hardly applied in the field of mm waves. In this analysis we also investigated the impact of various illumination parameters such as angle, frequency, phase and polarization for each type of image artifact. As such we could derive for each noise artifact the most suitable combination of illumination diversity techniques.

Recently a fully computer controlled scanning system has been implemented for recording images of multi-parameter illuminated scenes of 40 by 50 cm. This is a vital tool to give experimental backing for our diversity methods and to develop novel image processing algorithms on a multi-dimensional stack of speckled images. Scalar images can be recorded in the W-band (70-110 GHz). An example of processing a multi-dimensional recorded image (31x46 pixels) of a covered object is shown in the figure below. The 5 cm high word "LAMI" in aluminum foil is glued on a wavelength thick rectangular cardboard attached on a human body like material and covered with a T-shirt. The image on the left is a single illuminated image at 94 GHz. The middle one is obtained by applying the principal component analysis (PCA) technique on a set of images recorded at different angles and the right-hand side one is obtained after applying a despeckling algorithm, whereby speckle contrast image is subtracted from the PCA image. It is worth to draw the reader's attention to the fact that the typical wavelength here is more than 3 orders of magnitude larger than in the visible. This leads to a fundamentally new interpretation of surface structure and object geometry, which tend to coalesce in this spectral range.



(a) Original mm-wave image of the object (b) image improved with principal component analysis; (c) image improved by means of a despeckling algorithms.

Since spring 2005 the research efforts could be considerably extended by means of an SBO-IWT research project in collaboration with K.U.Leuven, UGent, UCL and IMEC and coordinated by ETRO-VUB to develop an intelligent feed-back. ■