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**Three Dimensional Face Recognition under Occlusion Variance**

**Abstract**

With advances in sensor technology, three dimensional (3D) face has become an emerging biometric modality, preferred especially in high security applications. However, dealing with occlusions covering the facial surface is a great challenge. In this thesis, we propose a fully automatic 3D face recognition system, attacking three sequential problems: (1) Registration of occluded surfaces, (2) detection of occluded regions, and (3) classification of occlusion-removed faces. For the alignment problem, we propose an adaptively selected model based registration scheme, where a model is selected for an occluded face such that only the valid non-occluded patches are utilized in correspondence establishment. After registration, occlusions are detected, where we propose two different occlusion detection approaches. In the first detector, fitness to a pixel-wise statistical model of the facial surface is used. In the second approach, in addition to the facial model, neighborhood information is incorporated. For occlusion handling, two different strategies are evaluated: (1) Removal of occlusions, and (2) restoration of missing parts. In the classification stage, a masking strategy, which we call masked projection, is proposed to enable the use of subspace analysis techniques with incomplete data. Experimental results on two databases with realistic facial occlusions, namely, the Bosphorus and the UMB-DB, confirm that: (1) The proposed registration technique based on the adaptively selected model is a good alternative to obtain occlusion robustness; (2) in occlusion detection, use of a statistical facial model is beneficial to make a pixel-wise decision, which can further be improved by incorporating neighborhood relations to model coherency of surfaces; (3) restoration provides only an approximation of the surface and is not suitable for classification purposes, (4) masked projection serves as a viable approach to apply subspace techniques on incomplete data.

**PUBLICATIONS**

**Journals**

1. **N. Alyuz**, B. Gokberk, L. Akarun, “3D Face Recognition under Occlusion using Masked Projection”, *IEEE Transactions on Information Forensics and Security*, May, 2013.
2. **N. Alyuz**, B. Gokberk, L. Akarun, “Regional Registration for Expression Resistant 3-D Face Recognition”, *IEEE Transactions on Information Forensics and Security*, Vol. 5, No. 3, pp. 425-440, September 2010.

**Book Chapters**

1. **N. Alyuz**, B. Gokberk, L. Akarun, “Robust 3D Face Recognition in the Presence of Realistic Occlusions”, *Face Recognition in Adverse Conditions*, Editors: M. Marsico, M. Nappi, M. Tistarelli, (ISBN: 978-1-4666-5966-7), IGI Global, 2014.

**Conferences**

1. **N. Alyuz**, B. Gokberk, L. Akarun, “Detection of Realistic Facial Occlusions for Robust 3D Face Recognition”, *International Conference on Pattern Recognition (ICPR)*, Stockholm, Sweden, August 24-28, 2014.

2. **N. Alyuz**, B. Gokberk, L. Akarun, “Adaptive Model Based 3D Face Registration for Occlusion Invariance”, *European Conference on Computer Vision (ECCV) Workshops - Benchmarking Facial Image Analysis Technologies (BeFIT)*, Florence, Italy, October 7-13, 2012 (best paper award).
3. **N. Alyuz**, B. Gokberk, L. Spreeuwers, R. Veldhuis, L. Akarun, “Robust 3D Face Recognition in the Presence of Realistic Occlusions”, *IAPR International Conference on Biometrics (ICB)*, New Delhi, India, March 29 - April 1, 2012.
4. **N. Alyuz**, B. Gokberk, L. Akarun, “A 3D Face Recognition System for Expression and Occlusion Invariance”, *IEEE International Conference on Biometrics Theory, Applications and Systems (BTAS)*, Arlington, Virginia, USA, September 29 - October 1, 2008.
5. **N. Alyuz**, B. Gokberk, L. Akarun, “Masked Projection for 3D Face Recognition under Occlusion”, *IEEE Conference on Signal Processing and Communications Applications (SIU)*, Trabzon, Turkey, April 23-25, 2014.
6. **N. Alyuz**, B. Gokberk, L. Spreeuwers, R. Veldhuis, L. Akarun, “Occlusion-robust 3D Face Recognition using Restoration and Local Classifiers”, *IEEE Conference on Signal Processing and Communications Applications (SIU)*, Antalya, Turkey, April 20-22, 2011.
7. **N. Alyuz**, B. Gokberk, L. Akarun, “Regional Registration and Curvature Descriptors for Expression Resistant 3D Face Recognition”, *IEEE Conference on Signal Processing and Communications Applications (SIU)*, Antalya, Turkey, April 9-11, 2009.

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