Int J Comput Vis
DOI 10.1007/s11263-013-0661-9

Using Bounded Diameter Minimum Spanning Trees to Build Dense Active Appearance Models

Robert Anderson · Björn Stenger · Roberto Cipolla

Received: 29 January 2013 / Accepted: 14 September 2013

Abstract We present a method for producing dense active appearance models (AAMs), suitable for video-realistic synthesis. To this end we estimate a joint alignment of all training images using a set of pairwise registrations and ensure that these pairwise registrations are only calculated between similar images. This is achieved by defining a graph on the image set whose edge weights correspond to registration errors and computing a bounded diameter minimum spanning tree. Dense optical flow is used to compute pairwise registration and a flow refinement method to align small scale texture is introduced. Further, given the registration of training images, vertices are added to the AAM to minimise the error between the observed flow fields and the flow fields interpolated between the AAM mesh points. We demonstrate a significant improvement in model compactness.

Keywords Active appearance models · Groupwise registration · Minimum spanning trees

1 Introduction

Active appearance models (AAMs) are statistical models of both shape and appearance. Since their introduction 15 years ago (Cootes et al. 1998), they have been used extensively for tracking as they allow robust and efficient registration over a variety of different object classes (Cootes and Taylor 2001; Matthews and Baker 2004; Mittrapiyanuruk et al. 2004). More recently, AAMs have been growing in popularity for synthesis of faces, for example in emotion synthesis (Abboud et al. 2004), expression transfer (Theobald et al. 2007) and visual text-to-speech applications (Deena et al. 2010). In order to train an AAM, a set of points must be consistently labelled in a collection of training images. Since this is usually carried out by hand the number of points is small (<100), leading to models such as the one in Fig. 1a. While automatic model building methods have been proposed previously (Baker et al. 2004; Ramnath et al. 2008; Walker et al. 1999), these do not produce results of sufficient accuracy for the synthesis of high-resolution images.

The task addressed in this paper is building dense AAMs, such as the example shown in Fig. 1b, in order to generate new video-realistic synthetic sequences. The underlying problem that needs to be solved in order to build such models is one of joint non-rigid image alignment. There exists a large body of work on this problem (Cootes et al. 2010, 2005; Cristinacce and Cootes 2008; Hamm et al. 2010; Hill et al. 2001; Learned-Miller 2006; Marsland et al. 2003; Sidorov et al. 2009), the majority of which registers each image to an iteratively updated base model. In this paper we propose a method that instead of registering all images to a base model registers images in a pairwise fashion. We find a bounded diameter minimum spanning tree (BDMST) on a graph containing all of the images, where each image is a node and each edge represents a warp between the two images it connects (see Fig. 1c). The motivation for this approach is the fact that with current pairwise registration methods a low alignment error can only be achieved between similar images. Given the spanning tree all images can be registered to a common reference frame, solving the joint alignment problem.

In this paper we use a dense optical flow algorithm to align two images. Current methods use a coarse-to-fine approach, which often fails to register small scale texture.

R. Anderson (✉)· R. Cipolla
Department of Engineering, University of Cambridge, Cambridge CB2 1PZ , UK
e-mail: ra312@cam.ac.uk

B. Stenger
Toshiba Research Europe Ltd., Cambridge CB4 0GZ , UK

Published online: 27 September 2013