# Guest Editorial: 3-D Image Analysis and Modelling

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IN the recent days, Three-dimensional (3-D) images are widely used for a lot of applications, and recent advances in computer performances have extremely extended the range of applicability. This vitality is witnessed by the increasing number of papers presented in past conferences and by the number of research projects related to 3-D images. Three-dimensional data are inherently more informative, in geometrical terms, than simply optical data, but also pose difficult problems that should be faced to obtain a reliable processing framework. Range resolution, type of noise, surface material are all aspects that should be considered in relationship with the sensing device and the application domain.

*Analysis* is a very broad field, in this special issue we interpreted it as the recovery of abstract information from 3-D data, e.g., surface characterization, segmentation, object recognition.

A main issue in both Computer Vision and Computer Graphics is *modelling*. Its goal is to obtain the geometrical structure of an observed scene, i.e., to recover reliable 3-D information from data, and to compute an efficient representation. It plays a central role as almost all processing algorithms have a close relationship to modelling, including analysis. For instance, characterizing local surface properties may be useful to improve the registration of several 3-D images, hence facilitating the construction of a complete 3-D model. Segmentation and object recognition techniques could consider the product of the modelling phase to obtain a reliable interpretation of a scene.

In this special issue, 49 papers have been submitted, reflecting the state of the art in research, development, and applications of 3-D image analysis and modelling. Eighteen papers have been finally selected via a single-blind review procedure by two referees for each submission. These papers illustrate topics at the forefront of both research and applications, demonstrating the contribution of this field to the Information Technology. They can be loosely organised into the following four categories: analysis and segmentation, modelling, surface matching and object recognition, applications.

*Image analysis*, and in particular segmentation, are of paramount importance for high-level processing and understanding of a 3-D scene. Depending upon the specific application and the type of 3-D data, several techniques are proposed, ranging from Hough-based algorithms to probabilistic, and morphological techniques.

Behrens *et al.* deals with the segmentation of tubular structures in 3-D image data. The algorithm is based on an extension of the randomised Hough transform. Tubular structures are modelled as generalised cylinders and tracked through 3-D space with a Kalman filter.

Svensson and Aronsson address the volume data processing for fibre paper inspection purposes. The problem was to analyse volume images of paper for the understanding the some properties of the fibre network in terms of optical and mechanical properties. Distance transform based methods have been used to obtain data representations, from which it is possible to assess thickness, length, curl, and other properties of the fibre, as well as to improve a qualitative visual inspection of the paper internal structure.

Bonnassie *et al.* proposed a method of analysis of 3-D images based on the classification of the medial axis in 4 classes: boundary, branching, regular, and arc points. This algorithm operates on the medial axis, and is based on the topological properties of a local region of interest around each voxel. Owing to the reversibility properties of the medial axis, this method can be extended to classify the original observed object.

Wang *et al.* coped with the problem of 3-D biological object detection and labelling in 3-D confocal fluorescence microscopic images. They proposed a statistical nonparametric framework, in which photometric and geometric models are embedded to identify objects of interest. The method is subdivided in two stages: the first phase consists in validate the photometric model, and results in an over-segmentation of the image; the second phase consists in an iterative merging procedure, taking into account textural, surface, and shape information.

*Modelling* – in the Computer Vision meaning – amounts to recovering the structure of the scene from images. The *Structure/Shape from X* problem is a classical issue in Computer Vision.

Yaşar *et al.* describe with details a complete end-to-end system for the acquisition of the 3-D model of an object from its silhouettes. A fine tuning using photo-consistency is eventually applied. Hock Soon Seah and Kok Cheong Wong propose a method of identifying planar objects from a single image and estimating their poses in space provided a set of models of planar objects is presented. The basic idea here is to synthesise virtual images of candidate models and then to compute the homography between the virtual and real input images. The objects are finally identified by comparing shapes recovered from decomposition of the homography.

*Modelling* – in the Computer Graphics meaning – involves building an accurate surface representation of the range data. Park *et al.* propose an efficient multi-resolution topology estimation of measured 3-D range data. For obtaining 3-D models from measurement, mesh topology should be recovered appropriately so that the object shape can be correctly represented. Their method can generate equiangular mesh models with small errors at various mesh resolutions.

More recently, at the convergence of Computer Vision and Computer Graphics, the *Plenoptic Modelling* paradigm appeared, whose aim is to recover the plenoptic function, that is the 5-dimensional function representing the intensity of the light observed from every position and direction in space. A spherical panorama or an omnidirectional image can be viewed as a sample of the plenoptic function at a fixed position. Nagahara *et al.* introduce a method for improving resolution of omnidirectional camera for 3-D environment modelling. Omnidirectional cameras have recently been used for capturing 360 degrees environment, but the resolution is limited because omnidirectional image is just captured into one image sensor.The proposed algorithm improves the resolution of the captured image by accurate registration of image sequence and merging them into higher resolution image.

When the time dimension is added, the modelling of dynamic surfaces deformation becomes an issue. In their paper, Lihua You and Jian Zhang propose a representation for dynamic surface modelling with a set of dynamic partial differential equations. To alleviate the excessive computational burden for solving the equations, the authors developed a method of constructing an effective solution function by some special treatment of the boundary conditions.

Object recognition is a classic and complex problem in Computer Vision, and, when dealing with 3-D images, several issues need to be considered and solved using adequate methods. One of the most investigated issue, strictly associated to the recognition, is the *registration* or *alignment* of 3-D images, also known as *pose estimation*. One way to perform registration is match surfaces using local features.

Sun *et al.* propose a new local feature – called point fingerprint – for surface characterization, consisting of the set of 2D contours that are projections of the geodetics circles on the tangent plane. Such a feature has been applied to surface matching, but can be used in a large variety of tasks. The paper by Hameiri and Shimsoni also deals with local feature extraction, namely principal curvature and *Darboux* frame. Modifications to state-of-the-art algorithms are introduced to allow the reliable extraction of such features from real data. Csakany and Wallace are also concerned with local surface features, but with the aim of classify 3-D objects. Surface patches are characterised using a modified Gaussian image that includes the local shape index. Learning and class generation are key components of the work. The system learns by example: during classification, the approach makes use of similarity measures to arrive at a final likelihood of membership of an unknown object of a class. Hoover *et al.* address directly the problem of estimating the motion of a range camera. Starting from a pair of partially overlapped range images, in which some objects can be modelled as planar surfaces (e.g., in an indoor environment for robot navigation), it is possible to solve the correspondence problem between the images in terms of planar surface equations, and then, compute the camera motion between the views. This is performed using the *space envelope*, which provides a more informative scene segmentation, followed by a matching phase between the segmented surfaces represented by topological graphs. Jaklic and Solina also deal with the registration of a pair of range images by pose estimation. They derived a closed form expression for 3-D Cartesian moment of super-ellipsoids, and show several properties for deformed and combined super-ellipsoids, also envisaging further applications in object recognition by moment invariants.

Finally, a lot of applications are active or can be invented owing to the increasing interest in 3-D images. Four papers have been selected devoted at tackling problems concerning the modelling of urban areas, cultural heritage, human-computer interaction, and underwater navigation. These papers represent a non-exhaustive list of disparate applications in which 3-D data can be usefully exploited.

In the paper ”A Vehicle-borne Urban 3-D Acquisition System Using Single-row Laser Range Scanners”, Huijing Zhao and Ryosuke Shibasaki describe a vehicle-borne system of measuring 3-D urban data by using two single-row laser range scanners. The two scanners are assigned different roles in the capture of urban site models. The horizontal range profiles are used to trace vehicle location, while the vertical profiles are main data sources for reconstructing the models.

In the framework of cultural heritage application, Guidi *et al.* describe the integration of a 3-D camera system with a close range digital photogrammetry technique, with the aim of enhancing the metric reliability of a 3-D model obtained from the alignment of many range maps.

In the paper “Visual Capture and Understanding of Hand Pointing Actions in a 3-D Environment: Design and Evaluation”, Colombo *et al.* focused on a Human-Computer Interaction application, in which a user can use gestures to manipulate information on displayed in a room wall using only hands as pointing devices. The method stands on a stereo setup in which a freely moving user is tracked in real-time, and his/her pointing gestures are remapped onto the screen. The proposed system results to be reliable, robust, and adaptive to user peculiarities and environmental changes.

Trucco and Curletto addressed an underwater application related to the estimation of 3-D data from a front-scan sonar image sequence. The problem is particularly complex, due to the low quality of images and the large uncertainty of the sensor positions. The method is subdivided in three steps: filtering, segmentation, and feature extraction, and tracking using a Kalman-based procedure. Results on synthetic and real sequences are reported, showing the robustness and reliability of the algorithm, despite the inaccuracies of the acoustic measures and the sensorial set-up.

As the selected papers reflect the vital activities in 3-D image processing research, we hope that this special issue will be a useful piece of work to the researchers’ community, and that it will stimulate new ideas and research projects. Last but not least, we would like to express our acknowledgements to the referees, who kindly spent their time and effort to review the submitted papers.

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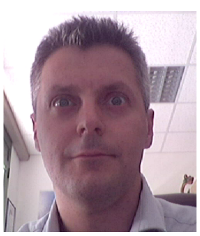

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