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An agent-based paradigm for the reconstruction of conical perspectives

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ABSTRACT

Obtaining three-dimensional models from digital images is one of the most important challenges in the computer vision. This task requires the advances in two major investigation fields: on the one hand the vectorization of the digital image to turn bitmaps into a set of geometrical entities (graph), on the other hand the reconstruction of the three-dimensional model from these two-dimensional entities. This work is focused on the second task, that is, the reconstruction of a three-dimensional model from a graph.

We have focused on the reconstruction of graphs with parallel and oblique perspectives with two vanishing points, and we propose an algorithm in order to identify this typology in contrast to the proposals kwon so far, in which it is assumed that the graph always represents an oblique perspective with three vanishing points from which greater information of the three-dimensional model can be extracted.

On the other hand, the current reconstruction algorithms require a previous knowledge of the faces defined in the model which must be obtained from the starting graph, task that is not currently solved completely, generates many erroneous results, requires interacting with the user and involves a high computing cost.

The reconstruction algorithms proposed in this work do not require the knowledge of the faces of the model, it is completely automatic and we have obtained a success rate of 100% in the graphs with normalon and quasi-normalon typology tested.

Regarding to practical advantages and research contribution in expert and intelligent systems, we propose, for the first time, an architecture based on agents for the reconstruction which allows, on the one hand, the simultaneous reconstruction of graphs considerably reducing the computing cost and, on the other hand, adding, with less effort, new reconstruction techniques to deal with graphs with other typologies.

1. Introduction

The investigations directed towards the reconstruction of models have experienced different advances according to the number of projections of the model available, being more significant when a greater number of them is available, which is obvious if we consider the increase in information that this involves.

There is a wide variety of reconstruction works presented from stereo images. Elsner, Whitaker, and Abidi (1999) proposed improvements in the reconstruction from a hybrid method which combines previous techniques. Gallego, Molina, Compañ, and Villagrá (2007) presented a system to obtain pixelated models for the reconstruction of environments. The last contribution in this direction which we are aware is the one presented by Correal, Pajares, and Ruz (2014) for the reconstruction of natural environments.

From the approach of reconstructing models from only one view on which this work is focused, the vast majority of the methods proposed are based on the study of orthogonal perspectives, which serve as a basis for the development of reconstruction techniques of conical perspectives.

Based on the labeling techniques for orthogonal projections initially proposed by Clowes (1971) and Huffman (1971) and later developed by Malik (1987), Parodi and Piccioli (1996) proposed a labeling method for conical perspectives that analyzed quantitatively the reconstruction of a 3D structure using geometrical restrictions provided by the location of the vanishing points. Their algorithm presented several advantages in relation to approaches based on linear programing ranging from less computing complexity to less error in the reconstruction of the 3D geometry. However, their algorithm requires that the starting projection does not have the representation of hidden edges given the

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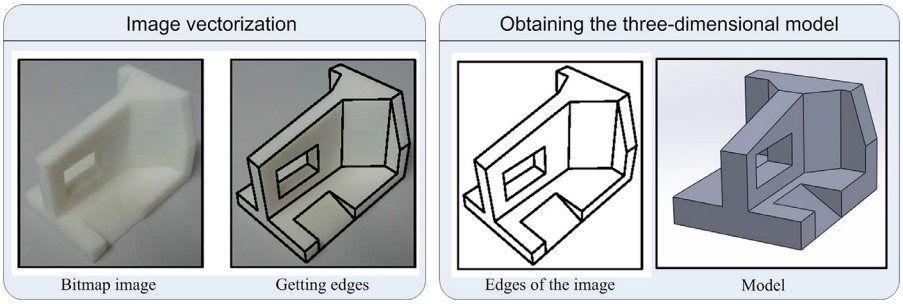

Fig. 1. Phases of reconstruction.

ambiguity that this representation means in the interpretation of the model.

On the other hand, perceptual methods have been one of the most used techniques in the reconstruction. Those methods, introduced by Marill (1991) for the reconstruction of orthogonal perspectives, are focused on optimizing an objective function that represents characteristics that a model must fulfill, deduced from its projection. Leclerc and Fischler (1992) and later Lipson and Shpitalni (1996) proposed modifications on the function to be optimized, however, because of the non-linearity of the objective function there are many local minimums and the expected result is not always achieved. Company, Contero, Conesa, and Piquer (2004) proposed initial tentative models in order to improve the optimization process. However, techniques based on optimization have the main disadvantage of a very high computing cost.

Liu, Cao, Li, and Tang (2008) proposed a new objective function based on linear restrictions wit he aim of avoiding obtaining local minimums in the reconstruction of models from conical perspectives. Their algorithm can deal with projections with or without hidden edges but, however, it requires knowing the defined faces of the model, and this is a non-trivial problem, it is not completely solved at present and it needs to interact with the user.

The latest investigation that follows the reconstruction approach from an only conical projection is due to Zou et al. (2015) who propose a semi-automatic reconstruction system which highlights obtaining an accurate model for a large class of objects; however, it requires interacting with the user in order to lead the algorithm in the reconstruction process.

The closest reference to this work can be found in Fang and Lee's proposal (2012), who starting from Lamb and Bandopadhay's ideas (1990) for the reconstruction of orthogonal perspectives expanded their method to conical projections. However, their method assumes that the projection always corresponds to a conical projection with three vanishing points, and it requires knowing the defined faces of the model once again.

In this work we present a reconstruction algorithm for polyhedrons with normalon and quasi-normalon typologies according to the proposal made by Dori and Tombre (1995), in which, for the first time, parallel and oblique conical projections with two vanishing points are analyzed. In comparison with prior works, our algorithm is characterized by not interacting with the user as it is completely automatic. It does not require knowing the defined faces of the model previously, and the starting projections can or cannot contain the representation of hidden edges. Moreover, we have implemented an algorithm that automatically analyzes the projection detecting its typology.

The use of expert and intelligent systems presents great advantages in recognizing scenes as it is stated in several works such as the one presented by Fernández-Pacheco, Albert, Aleixos, and Conesa (2012), in which a system based on agents for the recognition of sketches is used, or the one presented by Gomez, García, Mertín, De la Escalera, and Armingol (2015) where a detection system in real time for intelligent surveillance comparing consecutive scenes taken with a camera is proposed. Therefore, in this work we have implemented an architecture based on agents which, on the one hand, allows incorporating new algorithms for the reconstruction of models and perspectives with other typologies in an easy way and, on the other hand, reducing considerably the computing cost in the simultaneous reconstruction of models.

2. The paradigm of reconstruction

The reconstruction of a model from images obtained through photography requires two phases clearly distinguished: image vectorization and obtaining the three-dimensional model. The vectorization phase is focused on extracting all the geometrical entities (graph) from the images provided by the digital photography (bitmap). The obtaining the three-dimensional model phase aims to assign three-dimensional coordinates to each one of the entities defined in the graph (see Fig. 1).

In this work we propose a method for the automatic reconstruction of polyhedral models from the geometrical entities previously extracted from digital photographs through vectorization.

2.1. Typologies of the graph

Given the complexity of the problem proposed in this work we have focused on the reconstruction of polyhedrons with normalon and quasi-normalon typology according to the proposal made by Dori and Tombre (1995) (see Fig. 2):

- Graph normalon: this name is a generalization to the world of the polyhedrons of the concept of normalon polygons, such as those which have the property that all the angles between two convergent edges are of 90°. In Fig. 2 we can see a graph of this typology since all its edges converge to three points (one of them inappropriate).
- Graph quasi-normalon: they are graphs in which if we eliminate all the edges non-parallel to three directions converging in an angle of 90°, we do not lose the information of any of the vertices. In Fig. 2 we can observe a graph with this typology since the elimination of the edges 1–4, 2–3, 5–8 and 6–7 does not imply the loss of vertices.

2.2. Perspective types

The method proposed in this work aims to the reconstruction of graphs obtained from the vectorization of images captured with a camera. The conical perspective which studies the laws to represent with accuracy what it is observed is very similar to the optical system in photography since every picture is an image in central projection.

Taking a prism as a model, the conical perspective is considered (see Fig. 3):