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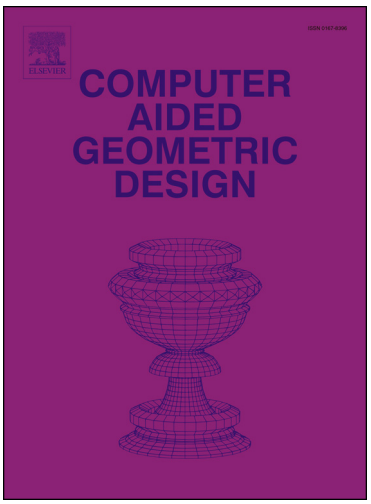

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Abstract

The preservation of the quality of 3D data along the possibly long chain from digital scanning to 3D model deployment is of paramount importance within an increasing number of advanced geometry design processes in the mesh domain, including digital fabrication. However, in many cases, model finalization is not a trivial task, especially when dealing with multiple dense meshes that are not watertight and may be generated by creative editing procedures such as partial model combinations, customized hollowing, free-form escape holes, sectioning planes or other cutting surfaces. This evidences how non-trivial mesh composition and completion responding to quality preservation needs is still challenging in various demanding application contexts. In this paper, we propose an extremely versatile solution that can handle all the previously described issues in a user-friendly way and which is based on an original multi-front advancing triangulation technique guided by implicit surfaces and based on a prioritization mechanism that drastically reduces front interferences, concurrently producing high quality meshing. Compared to other surface reconstruction, mesh completion and creative mesh editing solutions, our approach offers a high degree of preservation of the pre-existing mesh components, a high quality of interconnections between them and completion parts, the ability to track and to reproduce complex geometries and also to adapt to sharp geometric variations in the guiding field, typically emerging during advanced editing and finalization of 3D printable digital models.

1 Introduction

The production and editing of mesh models from scanned data are key factors in the evolving fields of digital design, additive and subtractive manufacturing. These require powerful, versatile and, at the same time, fast and intuitive ways to build high quality digital models. This is especially true when the desired final product is conceived to be an accurate replica or a creative editing and composition of unique geometries, coming from real world objects by means of high-end 3D scanning acquisitions. Articulated creative modeling processes need solutions for a list of mesh manipulation tasks involving the constituent parts of the final model and its finalization toward a technically realizable (*e.g.* 3D-printable) model. This may become not trivial at all, especially whenever standard procedures (*e.g.* automatic tools to create watertight models) fails or are not adequate to the aim of having full control on both the geometry and the quality of the final model.

Typical editing needs range from various kind of gap completion and hole filling, to the creation of highly customizable shells, hollows or other structures (such as cuts, escape holes for the drainage of excess material), to the composition of a model from sections or portions of various captured or designed parts. Providing satisfactory responsiveness to all of the above needs with a single geometry processing approach (that remains within the mesh editing domain) still represents an open challenge.

Model finalization mainly requires the generation of missing mesh portions from incomplete data. This can be solved by following a "guide" coming from implicit surfaces created from the available data and other external inputs. A very intuitive solution that one can think to adopt is that of an *advancing front* completion that follow the guiding field. However, the versatility required to such a tool, combined with the typical front interference issues, do not allow to find, among known solutions, an approach that meets all the desired requirements, especially in cases we also want to guarantee full *preservation of the input data*.

In this work, we introduce a novel approach to highly versatile data-preserving model completion and composition, particularly indicated for the reduction of the user burden in performing the above operations by means of an intuitive editing entirely done in the mesh domain. To this aim, we propose a revisited Marching Triangles algorithm based on an underlying guiding field to fully preserve the original mesh portions (no remeshing is needed) and seamlessly producing high quality triangles, even in presence of abrupt variations of the guiding field. Our solution provides advanced functionalities, not supported in other mesh completion solutions, in terms of handled geometries and quality of the generated patches.

Thanks to an effective advancement prioritization, to an original interference reduction policy, to a guaranteed re-projection on the guiding surface and to a dedicated mesh border pre-conditioning, the generated geometry seamlessly integrate with the existing one and the method guarantees a high quality and uniformity of the triangulation also whether the guiding surface bends significantly. Our results demonstrate, for different kind of meshes and modeling goals, the versatility, effectiveness and robustness of the proposed method which is also very fast in its execution. In particular, while traditional Marching Triangles [18] and Advancing Front methods [37, 38] are conceived for conventional meshing/re-meshing contexts, our technique is also suitable to be used in more articulated completion/composition pipelines that we exemplify in the domain of digital fabrication modeling. To give immediate insights about the proposed solution, the exemplary case of Fig.1 shows the intended use of our solution within an articulated digital modeling and fabrication pipeline (more details can be found in Sec.4).

2 Related work and contribution

Our work is mostly related to the geometry processing topics of *mesh generation* and *mesh completion*. Since both have been widely investigated, we limit our examination to the main contributions that are concurrently close to the considered requirements, evidencing their potentials or limitations in the finalization of quality digital models and defining the context for our technical and methodological contributions.

2.1 Mesh generation by advancing on implicit surfaces

Since we generate mesh patches to complete missing parts and to create connecting structures, our contribution is intrinsically related to the wide field of mesh generation techniques (for a a recent survey on polygonization of implcit surfaces we refer the reader to [14]). In particular, the proposed method can be seen as a revisited *Marching Triangles* (MT) algorithm. With respect to traditional MT methods (*e.g.* [18, 17]), our improved technique is more versatile and can be thus applied with more generality.