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# A system for editing triangle mesh sequences with time-varying connectivity

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## 1 Introduction

Recently, the demand for realism in 3D modeling and animation has grown, and the modeling process has become extremely time-consuming. This has made the possibility of 3D scanning surface geometry and motion attractive. Unlike traditional 3D modeling methods, 3D scanning typically produces time-varying mesh (TVM) sequences.

TVM sequences are characterized by a lack of temporal correspondence between consecutive frames, which is a property that many mesh processing methods rely on. This creates a demand for new TVM sequence editing methods. In this work, a volume element tracking system that was recently developed at the University of West Bohemia by Dvořák et al. (2021, 2022) is used to implement a TVM sequence editing method with a virtual reality interface.

## 2 Proposed method

A four-step pipeline for editing TVM sequences was proposed. The steps of this pipeline are designed to be executed independently and when needed, their specific algorithms should be easy to replace by other, more advanced implementations.

The user initiates the editing process by introducing a translation $\mathbf{t}_i$ into the model by manipulating the volume element $\mathbf{c}_i$. Volume elements are also called centers of the sequence. Next, the translation $\mathbf{t}_i$ is propagated to other centers $\mathbf{c}_j$ within the same frame of the sequence using an editing area of effect with a Gaussian falloff. The translation effect $w_j$ is controlled by a $\sigma$ parameter and calculated as per equation (1). The translation of center $\mathbf{c}_j$ can therefore be described as $\hat{\mathbf{c}}_j = \mathbf{c}_j + w_j \mathbf{t}_i$, where $\hat{\mathbf{c}}_j$ is the new position of the center $\mathbf{c}_j$ after editing.

$$w_j = \exp\left(-\sigma \cdot \|\mathbf{c}_i - \mathbf{c}_j\|^2\right), \quad \sigma \in \mathbb{R}_{>0} \tag{1}$$

Once the motion has been distributed to all of the affected centers within one frame, their motion should be distributed to other frames. This is done by transferring the translation vector $\mathbf{t}_i$ into the local coordinate system of other frames by finding the optimal rotation $\mathbf{R}^f$ of the neighborhood of the edited center $\mathbf{c}_i$ for each frame $f$. The translation vector is transformed frame-by-frame between neighboring sequence frames, as described by equation (2), where the translation $\mathbf{t}_i^{f-1}$ is transformed using the optimal rotation $\mathbf{R}^f$ to get the new translation vector $\mathbf{t}_i^f$. This vector is then used to distribute the effect of editing in frame $f$.

$$\mathbf{t}_i^f = \mathbf{R}^f \mathbf{t}_i^{f-1} \tag{2}$$

Finally, the motion of centers can be used to deform the surface in each frame of the sequence. In frame $f$, nearest neighboring centers to each vertex $\mathbf{v}_i^f$ of the surface can be

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discovered, and a translation of the vertex to its deformed position $\hat{\mathbf{v}}_i^f$ can be determined by weighing the motion of these centers from their unedited positions $\mathbf{c}_j^f$ to their positions $\hat{\mathbf{c}}_j^f$ after deformation. The weight $\bar{w}_j$ can be calculated by comparing the distance $d_j$ of a neighboring center to the distance $d_k$ of the farthest neighboring center and normalizing so that $\sum_j \bar{w}_j = 1$, as shown in equation (3).

$$\hat{\mathbf{v}}_i^f = \mathbf{v}_i^f + \sum_{j=0}^{k-1} \bar{w}_j(\hat{\mathbf{c}}_j^f - \mathbf{c}_j^f) \qquad w_j = 1 - d_j/d_k \qquad \bar{w}_j = \frac{w_j}{\sum_j w_j} \tag{3}$$

## 3 Results

The editing method in its current state has been tested and shown to be well suited for some types of intended deformation. The shape of the effector's area of effect makes the method well suited for adding rounded features to models and making small localized corrections, such as adjusting the shape of an area of a model's body or changing their facial features. Results can be seen in Fig. 1. Attempts at deforming larger areas of models, such as attempts at changing arm or leg positions, did not lead to good results, which is expected, since the area could not be properly captured by the shape of the effector.

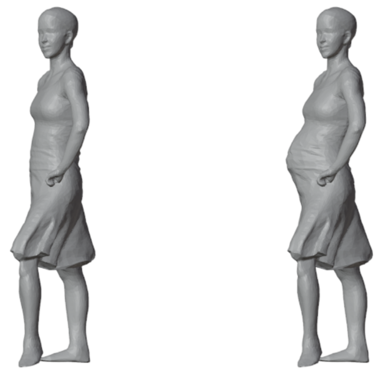

**Figure 1:** Input sequence (left) and editing result (right).

## 4 Future work

Directions for further development of the method were proposed as a part of the work. The suggestions included implementing effect weight painting and position locking, implementing a rotation tool that would enable larger scale deformations such as limb repositioning, and optimizing the surface deformation phase by using compactly supported functions to model the area of effect, which could dramatically decrease the number of processed vertices.

## References


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