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Multi-scale mesh saliency with local adaptive patches for viewpoint selection

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Our visual attention is attracted by specific areas into 3D objects (represented by meshes). This visual attention depends on the degree of saliency exposed by these areas. In this paper, we propose a novel multi-scale approach for detecting salient regions. To do so, we define a local surface descriptor based on patches of adaptive size and filled in with a local height field. The single-scale saliency of a vertex is defined as its degree measure in the mesh with edges weights computed from adaptive patch similarities weighted by the local curvature. Finally, the multi-scale saliency is defined as the average of single-scale saliencies weighted by their respective entropies. The contribution of the multi-scale aspect is analyzed and showed through the different results. The strength and the stability of our approach with respect to noise and simplification are also studied. Our approach is compared to the state-of-the-art and presents competitive results.

1. Introduction

In every look thrown at a scene or an object, our attention is attracted by particular regions distinct from the surrounding zones. These striking areas, essentially prominent in the field of 3D objects, are content dependent. However, they are not dependent of the behavior or the experience relative to the human observer [1]. Therefore, saliency computation can allow detecting perceptually important points or regions on the surface of a 3D mesh. The saliency models proposed in the state-of-the-art are inspired from the HVS's (Human Visual System) low-level features. This allows us to replace the geometrical attributes used for the computation of saliency by perceptual ones, and as confirmed in [2], these perceptual models reach to model correctly the eye movement of the humain observer.

Many applications in 3D computer vision benefit from visual saliency, we can mention: optimal view point selection [3] where the objective is to generate the most informative viewpoints that capture a maximum of salient regions, and adaptive mesh simplification [4] that aims at maintaining the best perceived quality by performing simplification essentially on regions of low saliency. Likewise, shape matching [5], mesh resizing [6], and face recognition [7] can take advantage from saliency detection.

2. State-of-the-art

Unlike 2D images where saliency was amply dealt with (see [8] and references therein), there is few work on the evaluation of saliency directly on the geometry of the 3D meshes. For example, Lee et al. [3] were the first to propose a model based on the computation of curvature [9]. The saliency at a vertex is defined as the absolute difference between the gaussian weighted averages at both fine and coarse scales, respectively defined as σ and 2σ (the bandwidth of the Gaussian filtering scales).

Tal et al. [10] detect salient regions of interest of surfaces with the combined use of vertex distinctness and shape extremities. Vertex distinctness is computed from a similarity

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measure obtained with the diffusion distance between Spin Image 2D histograms [11]. Shape extremities are obtained from extreme geodesic distances on a MDS-transformed mesh.

In [12], Wu et al. detect salient regions with a descriptor measuring the local height field into the neighborhood of each vertex; a square map of projection heights [13] is generated to denote its form. Local and global saliencies are computed for each vertex. The final visual saliency of a vertex is computed by combining the global and local saliencies at different scales.

In [14], Zhao et al. proposed a saliency detection method based on a sampling for 3D mesh simplification. The approach begins by applying a Gaussian filter to the vertices. Then, parameters representing the mean curvature and the principal curvatures at different scales are computed. Finally, the different maps are filtered by a median filter before being combined to produce the final saliency map.

Acting on the same principle, the same authors Zhao et al. proposed in [15] a saliency model based on the index surface diffusion, likewise computed in [14], but with a non-local filter [16]. This model was integrated in applications for mesh registration and mesh simplification.

In [17], Zhao and Liu detect salient regions by diffusing the surface index with a non local filter [16]. This time, the method is based on volumetric 3D patches. The approach begins by filtering the mesh to delete high frequencies and compute similarities between vertices. Afterwards, the mesh is transformed into multi-scale volumetric data. The dissimilarity between two patches located in two sub-voxels allows us to generate a dissimilarity map. Finally, the saliency of one patch, which is proportional to its dissimilarity, is defined by the average of the saliency maps across the different scales.

Song et al. suggested in [18] to integrate the CRF (Conditional Random Field) framework to detect saliency. The multi-scale representation generated is combined using CRFs in order to label the mesh regions into salient and non-salient areas. Then, the method incorporates the multi-scale information of a mesh into a Conditional Random Field (CRF) framework while introducing a consistency constraint. Finally, to assign a label to each vertex, the CRF is resolved with the Belief Propagation algorithm.

In [19], Zhao et al. detect points of interest by estimating the saliency. The Retinex theory [20] is implemented to enhance the local details and estimate the invariant properties of the surface views. After the segmentation of the surface, the saliency estimated is based on the spatial distance between the resulting segments.

Recently, Song et al. suggested in [21] to estimate the saliency in the spectral domain by analyzing the irregularity spectrum of the Log-Laplace operator. First, the spectrum of the Laplacian is calculated, then a logarithmic transformation is applied to the spectrum to amplify variations at low frequencies while removing them from the rest of the spectrum. These deviations represent saliency.

3. Contributions

As described above, most of existing approaches estimating 3D mesh saliency include a simplification step in their process to define a good ratio between Sailency and Noise that is sometimes difficult to precise. This simplification step inevitably removes vertices from the mesh geometry and therefore alters the surface and its initial fluctuations. The result is then a measure of saliency that does not take into account local variations and exiguous irregularities, yet necessary for the accurate estimation of saliency on surface meshes. Other steps such as smoothing bring back to a very high complexity.

It is commonly accepted that the human visual system is sensitive to large fluctuations surfaces [22]. Thereby, if a mesh vertex stands out strongly from its neighborhood, then this vertex could be considered as salient point. It remains to define the way in which we can locally evaluate the saliency of a vertex within the mesh. For this, local robust descriptors are carried out.

In this paper we propose a new method to define a perceptual multi-scale saliency map for 3D meshes. A synopsis summarizing the proposed approach is shown in Fig. 1.

The novelty of the proposed approach relies on several key points. First, patches of adaptive size are used as local vertex descriptors. The dynamic size of the patches offers a better consideration of shape irregularities. Second, the saliency is defined as the vertices's degree measures with edges weights accounting for vertices similarities. The computation of the dissimilarity between patches benefits from a scale parameter. The distance between patches is weighted by the curvature of the target vertex to consider the local curvatures. Third, the weights used to aggregate the saliencies at different scales are based on their respective entropy in order to take into account the disparity of the saliency information in each scale. Other approaches measure saliency at different scales without considering the entropy criterion [3,10]. Also note that our approach is independent of any pre-treatment like simplification or smoothing. This autonomy will allow fitting this approach into any mesh processing algorithm. All these factors lead to an accurate estimation of visual saliency. It is also important to note that the proposed approach is an improvement of our recent work [23]. The main differences between the work in the present paper and [23] are:

1. The adaptive patch orientation and its construction are computed according to a spherical neighborhood rather than one-ring neighborhood (improving robustness).
2. The curvature of the mesh surface is taken into account in the computation of visual saliency.
3. The multi-scale aspect is added (improving the measure

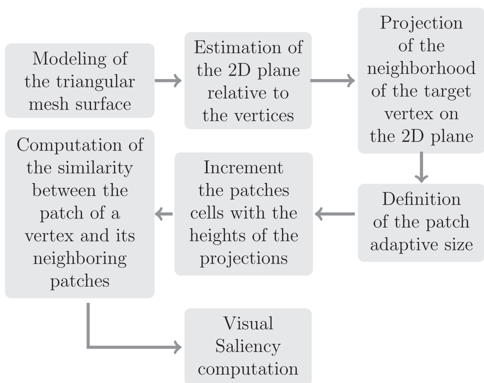

Fig. 1. Synopsis of the mono-scale saliency.