Representing 3D Texture on Mesh Manifolds for Retrieval and Recognition Applications

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The full 3D shape information of a 3D object can be preserved and encoded in a simple, compact and flexible format by the triangular mesh manifold modality, which also allows the integration of both photometric and geometric information into a single support. However, despite the abundance and the richness of the mesh manifold modality, the number of solutions for representing the geometry of 3D objects is still limited, and not comparable with the large variety of methods available in 2D. An evidence of this is given by the lack of efficient descriptors to represent the texture component associated to 3D objects.

This motivated us to focus on this aspect that can reveal new possibilities in 3D objects retrieval and recognition. Two different meanings are associated here to the term "texture": On the one hand, we consider the 3D *geometric texture* as a property of the surface, distinct from the shape, which is characterized by the presence of repeatable geometric patterns (Fig. 1, left). These patterns can be seen as geometric corrugations of the surface that do not alter the overall 3D shape, but rather change the local smoothness and appearance of the surface. This can result in 3D objects that show similar or equal shape, but very different 3D geometric texture; On the other, the 3D *photometric texture* attached to the mesh is related to the photometric appearance of the surface as captured by a 2D imaging sensor (Fig. 1, middle). Being attached to the triangular mesh, this property of the 3D surface is represented in the RGB domain. This is a different concept from the 2D texture, since it is represented on the mesh, rather than on the image plane, though using the same RGB domain of the 2D counterpart. These two properties may also be present together, for a 3D object characterized by both the 3D geometric and photometric texture (Fig. 1, right).

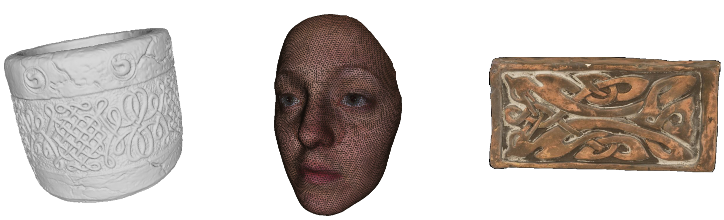

Figure 1: 3D objects with different textures: (left) 3D *geometric texture*, characterized by repeatable patterns of the mesh surface; (middle) 3D *photometric texture* attached to the triangular mesh. In this case, the textural information is most present in the photometric appearance of the mesh, rather than in the geometric appearance; (right) Combination of 3D geometric and photometric texture on a 3D mesh manifold.

In this work, we present a novel approach for holding both aspects within a single framework, targeting the problem of representing the texture properties of 3D mesh manifolds for retrieval and recognition applications. As a main contribution of this work, we propose a solution, which is based on the recently proposed mesh-LBP concept [3] to address the above challenges. In particular, to the best of our knowledge, this work is the first one to present and apply a unified framework, which enables an elegant and effective representation of 3D geometric and photometric texture.

Let $h(f)$ be a scalar function defined on the Ordered Ring Facets (ORF) of a mesh (Fig. 2), which can incarnate either a geometric (e.g., curvature) or photometric (e.g., color) information. The mesh-LBP operator is defined as follows:

$$meshLBP_m^r(f_c) = \sum_{k=0}^{m-1} s(h(f_k^r) - h(f_c)) \cdot \alpha(k), \quad s(x) = \begin{cases} 1 & x \geq 0 \\ 0 & x < 0 \end{cases}, \tag{1}$$

where r is the ring number, and m is the number of facets uniformly spaced on the ring. The parameters r and m control, respectively, the radial resolution and the azimuthal quantization. The discrete function $\alpha(k)$ is introduced for the purpose of deriving different LBP variants. For example, $\alpha(k) = 2^k$ results into the mesh counterpart of the basic LBP operator firstly suggested by Ojala et al. [2]; with $\alpha(k) = 1$, we obtain the sum of the digits composing the binary pattern.

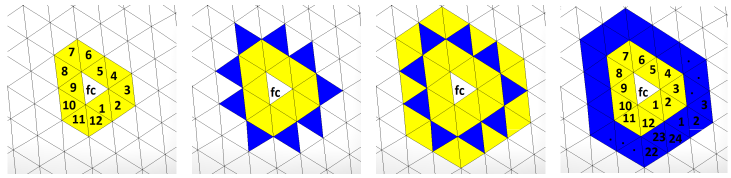

Figure 2: Generation of a sequence of rings of ordered facets (ORF) that provides the support for computing mesh-LBP.

Retrieval based on 3D geometric texture

This experiment aims to assess the mesh-LBP potential for detecting a specific type of 3D geometric texture in a given surface. Such capacity is useful in "3D texture retrieval" applications, where a sample of specific 3D texture (probe) is available, and we want to automatically detect regions, in a gallery surface, matching that particular sample. To the best of our knowledge, we are the first to attempt retrieving 3D geometric texture on a mesh manifold. To this end, we used a naive template-matching-like method, where the gallery mesh surface is browsed, and at each facet a texture descriptor is computed and compared to its probe texture model counterpart using a given metric (i.e., the Bhattacharyya distance in this application). Facets exhibiting a distance below a certain threshold are selected as a potential match. Results showcase the potential of the mesh-LBP and its superior performance for such a task in comparison with other standard descriptors.

Face recognition by fusing shape and 3D photometric texture

The effectiveness of LBP in 2D face recognition has been demonstrated in [1] and in several subsequent works. Motivated by these results, we investigate if a similar capability exists for the mesh-LBP. We propose an original mesh-LBP based face representation that can be constructed over triangular mesh manifolds, and relieves the recognition process from the need for normalization, while preserving the full 3D geometry of the shape. Furthermore, mesh-LBP construction allows boosting recognition by offering an elegant framework for fusing, over the mesh support, photometric texture and shape information at data and feature level, in addition to score and decision level. Our method encompasses the following stages: 1) Construction of a grid of points on the face surface, to obtain an ordered set of regions; 2) Computation of an histogram of the mesh-LBP descriptors computed on the surface region centered at each point of the grid; 3) Concatenation of the regional histograms into a structure encoding either a global or partial description of the face; 4) Performing the face matching with mesh-LBP descriptors based on 3D geometric texture and photometric appearance on the mesh, and their combination using different score-level and feature-level fusion strategies.

[1] T. Ahonen, A. Hadid, and M. Pietikäinen. Face description with local binary patterns: Application to face recogntion. *IEEE Trans. on Pattern Analysis and Machine Intelligence*, 28(12):2037–2041, Dec. 2006.

[2] T. Ojala, M. Pietikäinen, and D. Harwood. A comparative study of texture measures with classification based on featured distribution. *Pattern Recognition*, 29(1):51–59, Jan. 1996.

[3] N. Werghi, S. Berretti, and A. Del Bimbo. The mesh-lbp: a framework for extracting local binary patterns from discrete manifolds. *IEEE Trans. on Image Processing*, 24(1):220–235, Jan. 2015.

This is an extended abstract. The full paper is available at the Computer Vision Foundation webpage.