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# Weighted Graph-Based Assessment of Visual Quality in Triangular Mesh Models

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**Abstract.** This paper focuses on evaluating visual quality in triangular mesh models. We introduce a novel approach using weighted graphs to address this challenge, motivated by the increasing necessity for accurate quality assessment in fields such as computer graphics and 3D modeling. The methodology is initiated by generating saliency maps for each distorted mesh model. Then, we build a network representation where mesh vertices serve as nodes and mesh edges as graph edges. Vertex weights are determined based on saliency values, and a diverse set of topological properties are extracted and statistically measured to generate a signature vector. The quality score prediction is conducted through rigorous evaluation of three regression algorithms. Experiments cover four publicly available databases tailored for mesh model quality assessment, showcasing the superior performance of the proposed approach with significant correlations to subjective evaluations.

**Keywords.** *Weighted graph; quality assessment; triangular mesh; saliency.*

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## 1 Introduction

The increasing use of 3D models in various fields has led to a demand for robust methods to assess their visual quality, especially considering the potential distortions introduced during processing [1, 2]. Objective methods have emerged as practical solutions to streamline the traditionally human-intensive process of assessing distortion levels. These methods, categorized as full reference [3, 4], reduced reference [6], and blind methods [7, 8, 9, 10], with blind methods gaining particular significance, aim to replicate human judgments without relying on reference models. 3D meshes, complex structures comprising vertices, edges, and faces, are crucial for shaping 3D models, and selecting an appropriate data structure for representing them is essential for effective quality assessment. Graphs, being versatile data structures, have shown promise in addressing various challenges in computer vision, including tasks like image segmentation [11, 12, 13], classification [14, 15] and denoising [16, 1]. However, relatively few studies have explored graph-based approaches to assess 3D mesh quality, with existing methods often separately learning geometric and perceptual attributes without integration into the weighted graph construction process [17, 18]. In this paper, we propose a novel approach to assess the visual quality of 3D meshes using a weighted graph constructed from geometric coordinates and mesh vertices' saliency values. We subsequently train the graph's characteristics using a

machine learning-based regression method to predict the quality score.

## 2 Proposed method

The proposed method aims to evaluate the visual quality of 3D meshes by leveraging geometric and perceptual features extracted from fundamental mesh components. Fig. 1 illustrates the process. Initially, saliency maps are computed for each mesh, utilizing mean curvature and

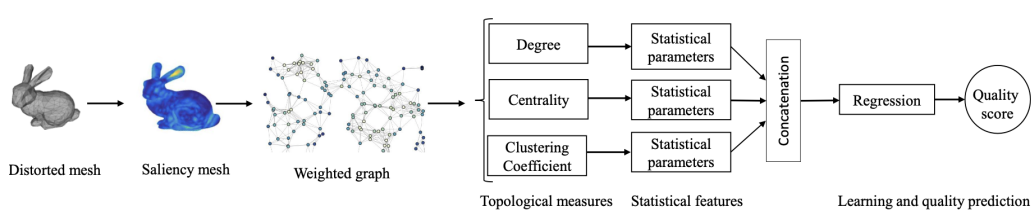


Figure 1: Scheme of the proposed method

Gaussian filters [19]. These maps are then used to calculate a weighted graph representation of the mesh, where vertices correspond to graph nodes and edges to graph edges. The graph is weighted based on a function considering Euclidean distance and saliency values. Local topological measures, including degree, degree centrality, and clustering coefficient, are derived for each mesh-weighted graph. Statistical parameters, estimated using the Gamma distribution, are obtained to represent the network structure.

$$p(x; \alpha, \beta) = \frac{\beta^{-\alpha} x^{\alpha-1}}{\Gamma(\alpha)} \exp\left(-\frac{x}{\beta}\right) \quad 0 < x < \infty \quad (1)$$

Where  $\Gamma(\cdot)$  denotes the Gamma function.

The statistical measure vector  $SM$  is a concatenation of degree statistics  $SM_d$ , degree centrality statistics  $SM_{dc}$  and clustering coefficient statistics  $SM_{cc}$  of the mesh network. For example,  $SM_d$  is defined by:

$$SM = \{\hat{\alpha}_d, \hat{\beta}_d, \hat{\alpha}_{dc}, \hat{\beta}_{dc}, \hat{\alpha}_{cc}, \hat{\beta}_{cc}\} \quad (2)$$

where  $\hat{\alpha}_d, \hat{\beta}_d, \hat{\alpha}_{dc}, \hat{\beta}_{dc}, \hat{\alpha}_{cc}, \hat{\beta}_{cc}$  are the estimated Gamma parameters of the probability density function of the mesh network, respectively. Finally,  $SM$  is input for regression algorithms to predict quality scores.

## 3 Experimental results

We perform a comparative analysis of three machine learning-based regression algorithms, Random Forest (RF), Support Vector Regression (SVR), and Generalized Regression Neural Network (GRNN), for forecasting mesh visual quality scores. We use a leave-one-out cross-validation (LOOCV) methodology, wherein a training regression model is constructed using all 3D objects in the repository, excluding one object and its distorted variants during each iteration. This omitted subset is the test set against which the established regression model is evaluated. This iterative procedure is repeated for every 3D object within the repository. Our evaluation is conducted on four datasets specifically curated for quality metrics assessment (LIRIS/EPFL General-Purpose database [20], LIRIS Masking database [21], UWB compression database [6], The IEETA simplification database [22]). These datasets comprise original and distorted meshes graded by human observers. Ensuring diversity in content and

distortion levels is imperative in dataset selection to reflect a comprehensive range of quality evaluation scenarios. We utilize The Pearson Linear Correlation Coefficient (PLCC) to assess the monotonicity of predictions relative to human observer scores. Additionally, the Spearman Rank-Order Correlation Coefficient (SRCC) measures the prediction accuracy concerning the ordinal ranks of the scores. First, we investigate the influence of saliency on quality score prediction by comparing weighted and unweighted graph-based techniques. Results, reported in Table 1, reveal notable performance advantages for weighted graphs across all mesh types and datasets. We observe significant disparities between regression techniques. The most effective strategy involves RF regression with weighted graphs. We also performed an extensive

Table 1: Performance with weighted and unweighted graphs on the four databases.

Regression	Method	Masking		General		Compression		Simplification	
		SRCC	PLCC	SRCC	PLCC	SRCC	PLCC	SRCC	PLCC
GRNN	Unweighted	70.6	63.2	63.8	61.4	64.5	60.0	59.4	65.5
	Weighted	82.8	81.2	83.8	80.1	82.0	79.0	78.3	80.4
SVR	Unweighted	74.2	62.4	63.9	65.0	63.1	61.4	62.2	67.8
	Weighted	87.6	86.3	89.4	82.5	87.2	82.6	80.9	83.1
RF	Unweighted	78.1	68.6	66.6	72.2	75.6	73.5	70.5	75.9
	Weighted	91.1	91.9	90.3	88.7	91.2	89.4	88.6	90.8

comparative analysis of the proposed method with alternative NR methods. Table 2 reports the results. It shows that the proposed method consistently outperforms many alternatives, with its scores often surpassing or closely approaching 92%. Notably, MVQ-GCN, NR-SVR, and NR-GRNN also demonstrate respectable prediction scores, with MVQ-GCN showing consistent performance across all databases.

Table 2: Performance of NR objective methods on the four databases.

Type	Method	Masking		General		Compression		Simplification	
		SRCC	PLCC	SRCC	PLCC	SRCC	PLCC	SRCC	PLCC
	NR-SVR [23]	91.1	89.1	84.6	86.8	85.5	88.1	88.9	87.6
	NR-GRNN [24]	90.2	82.4	86.2	88.7	86.3	86.7	87.7	88.0
	BMQA-GSES [17]	91.3	84.1	87.9	<b>90.5</b>	87.3	87.4	89.1	89.6
	MVQ-GCN [18]	<b>91.7</b>	90.9	89.3	88.6	90.5	87.7	<b>89.9</b>	89.4
	<b>Our method</b>	91.1	<b>91.9</b>	<b>90.3</b>	88.7	<b>91.2</b>	89.4	88.6	<b>90.8</b>

## References

- [1] Pastrana-Vidal, Ricardo R and Gicquel, Jean-Charles and Colomes, Catherine and Cherifi, Hocine “Frame dropping effects on user quality perception”, Proc. 5th Int. WIAMIS, 2004.
- [2] Pastrana-Vidal, Ricardo R and Gicquel, Jean C and Blin, Jean L and Cherifi, H, “Predicting subjective video quality from separated spatial and temporal assessment,” SPIE Human Vision and Electronic Imaging XI, Volume 6057, 2006, pp 276-286.
- [3] Guillaume Lavoué, “A multiscale metric for 3d mesh visual quality assessment,” in Computer Graphics Forum. Wiley Online Library, 2011, vol. 30, pp. 1427–1437.
- [4] Fakhri Torkhani, Kai Wang, and Jean-Marc Chassery, “A curvature tensor distance for mesh visual quality assessment,” Computer Vision and Graphics, pp. 253–263, 2012.
- [5] Massimiliano Corsini, Elisa Drelie Gelasca, Touradj Ebrahimi, and Mauro Barni, “Watermarked 3-d mesh quality assessment,” IEEE Multimedia, vol. 9,no. 2, pp. 247–256, 2007.
- [6] Váša, Libor, and Jan Rus. "Dihedral angle mesh error: a fast perception correlated distortion measure for fixed connectivity triangle meshes." In Computer Graphics Forum, vol. 31, no. 5, pp. 1715-1724. Oxford, UK: Blackwell Publishing Ltd, 2012.

- [7] Abouelaziz, Ilyass, and El Hassouni, Mohammed and Cherifi, Hocine(2017), “A convolutional neural network framework for blind mesh visual quality assessment”, IEEE International Conference on Image Processing (ICIP), pp755-759.
- [8] Abouelaziz, Ilyass and Chetouani, Aladine and El Hassouni, Mohammed and Latecki, Longin Jan and Cherifi, Hocine (2018), “Convolutional neural network for blind mesh visual quality assessment using 3d visual saliency”,25th IEEE ICIP, pp 3533-3537
- [9] Hamidi, Mohamed and Chetouani, Aladine and El Haziti, Mohamed and El Hassouni, Mohammed and Cherifi, Hocine(2019),” Blind robust 3D mesh watermarking based on mesh saliency and wavelet transform for copyright protection”, Information, Vol. 10, no 2,
- [10] Abouelaziz, Ilyass and Chetouani, Aladine and El Hassouni, Mohammed and Latecki, Longin Jan and Cherifi, Hocine (2020), “No-reference mesh visual quality assessment via ensemble of convolutional neural networks and compact multi-linear pooling”, Pattern Recognition,Volume 100, pp 107174, Elsevier.
- [11] Mourchid, Y., El Hassouni, M. and Cherifi, H. A general framework for complex network-based image segmentation. *Multimed Tools Applications* 78, 20191–20216 (2019).
- [12] Rital, S and Bretto, A and Cherifi, H and Aboutajdine, D, “A combinatorial edge detection algorithm on noisy images”, International IEEE Symposium on VIPromCom Video/Image Processing and Multimedia Communications, pp 351-355.
- [13] Rital, Soufiane and Cherifi, Hocine and Miguët, Serge (2005), “Weighted adaptive neighborhood hypergraph partitioning for image segmentation,” ICAPR 2005, Bath, UK, August 22-25, 2005, Proceedings, Part II 3, pp 522-531, Springer.
- [14] Lasfar, A and Mouline, S and Aboutajdine, Driss and Cherifi, Hocine (2000), “Content-based retrieval in fractal coded image databases”, Proceedings 15th International Conference on Pattern Recognition. IEEE ICPR, Volume 1, pp 1031-1034
- [15] Demirkesen, Can and Cherifi, Hocine (2008), “A comparison of multiclass SVM methods for real-world natural scenes,” International conference on advanced concepts for intelligent vision systems, pp 752-763, Springer Berlin Heidelberg.
- [16] Hassouni, ME and Cherifi, Hocine, and Aboutajdine, Driss HOS-based image sequence noise removal.In *IEEE Transactions on Image Processing*, Vol. 15, no 3, pp 572—581, 2006.
- [17] Y. Lin, M. Yu, K. Chen, G. Jiang, F. Chen and Z. Peng, "Blind mesh assessment based on graph spectral entropy and spatial features", *Entropy*, vol. 22, no. 2, pp. 190, Feb. 2020.
- [18] I. Abouelaziz, A. Chetouani, M. E. Hassouni, H. Cherifi and L. J. Latecki, "Learning Graph Convolutional Network for Blind Mesh Visual Quality Assessment," in *IEEE Access*, vol. 9, pp. 108200-108211, 2021.
- [19] Lee, Chang Ha, Amitabh Varshney, and David W. Jacobs. "Mesh saliency." In *ACM SIGGRAPH 2005 Papers*, pp. 659-666. 2005.
- [20] Lavoué, Guillaume, Elisa Drelie Gelasca, Florent Dupont, Atilla Baskurt, and Touradj Ebrahimi. "Perceptually driven 3D distance metrics with application to watermarking." In *Applications of Digital Image Processing XXIX*, vol. 6312, 2006.
- [21] Lavoué, Guillaume, Mohamed Chaker Larabi, and Libor Váša. "On the efficiency of image metrics for evaluating the visual quality of 3D models." *IEEE Transactions on Visualization and Computer Graphics* 22, no. 8 (2015): 1987-1999.
- [22] Silva, Samuel, Beatriz Sousa, Carlos Ferreira, and Joaquim Madeira. "A perceptual data repository for polygonal meshes." In *Int. Conf. in Visualisation*, pp. 207-212. IEEE, 2009.
- [23] Abouelaziz, Ilyass, Mohammed El Hassouni, and Hocine Cherifi. "No-reference 3d mesh quality assessment based on dihedral angles model and support vector regression." In *International Conference on Image and Signal Processing*, pp. 369-377. Springer, Cham, 2016.
- [24] Abouelaziz I, El Hassouni M, Cherifi H A curvature based method for blind mesh visual quality assessment using a general regression neural network, *IEEE SITIS*,2016