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XXXIII Cycle

3D POINT CLOUD DENOISING USING A JOINT GEOMETRY AND COLOR *K*-NN GRAPH

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Research context and motivation

- Point cloud is an important representation of volumetric objects in three-dimensional space, which allows visualization from any viewpoint.
- The acquisition of a point cloud can be done using active sensors, or computed indirectly from multi-viewpoint images, the obtained point cloud suffers from the noise.
- The denoising of point cloud should be performed in order to improve the quality.
- The state-of-the-art technique denoised the geometry based on graph using geometry only.
- The disadvantage of the approach is that correct position of a point is estimated based on the graph signal representing the geometry only, the false surface is computed and as result holes are formed (See Fig. 1).

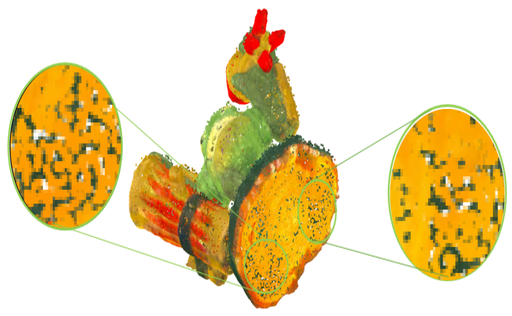

Figure 1: Green_monster model: Geometry denoising based on geometry only graph.

Addressed research questions/problems

- How to denoise the geometry of a point cloud having no adverse effects?
- The displaced points in a noisy point cloud are noise? and should we eliminate them or relocate to their original positions?
- Can we relocate the noisy points with the same color to the points in their proximity to their original positions? (See Fig. 2)

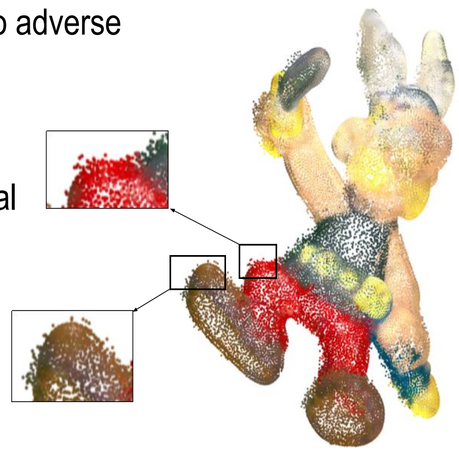

Figure 2: Asterix model: Noisy points with the same color in their proximity.

Novel contributions

Graph Construction

- Generate *K*-NN graph based on color similarity and geometry proximity in a 3D plane.
- Defining six-dimensional features for each point as $p_i = [w_1 X_i \; w_2 C_i]$, with $X_i = [\, x_{1i} \; x_{2i}, x_{3i}]$ and $C_i = [c_{1i}, c_{2i}, c_{3i}]$ where c_{1i}, c_{2i} and c_{3i} are the color attributes and x_{1i} x_{2i} and x_{3i} are the geometry coordinates of point i.

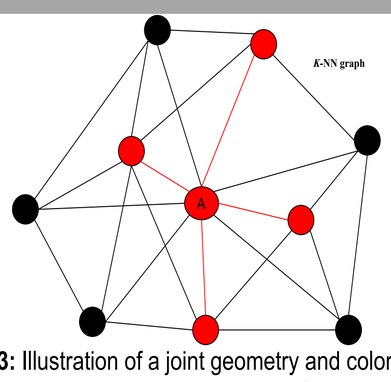

Figure 3: Illustration of a joint geometry and color k-NN graph, node A connected with red colored nodes analogous to same color in its proximity.

Adopted methodologies

Geometry Denoising

- Geometry denoising is performed by exploiting the graph G constructed from both geometry and color information of the noisy point cloud.
- Convex minimization problem is considered for denoising the graph signal with the limitation that the signal must be smooth on a graph.
- The denoising problem can be written as optimization problem represented by Eq.1

$$\dot{x} = \underset{x}{argmin} \|x - g\|_2^2 + \gamma \|\nabla_G x\|_2^2. \qquad (1)$$

- Where $\dot{x}$ is the approximated denoised signal, the noisy signal is represented by g, γ is a parameter for regularization and $\nabla_G x$ represents the gradient of the signal x on the graph G.

Submitted and published works

- Final draft of a conference paper is ready for submission to ICASSP.
- Drafting of Journal paper is in progress.

Results

Natural Point clouds with real noise

- Demonstrate the visual comparison of the proposed algorithm with the denoised point cloud using a graph construction based on geometry only.
- The qualitative comparison has been made on both the real world and synthetic point clouds.

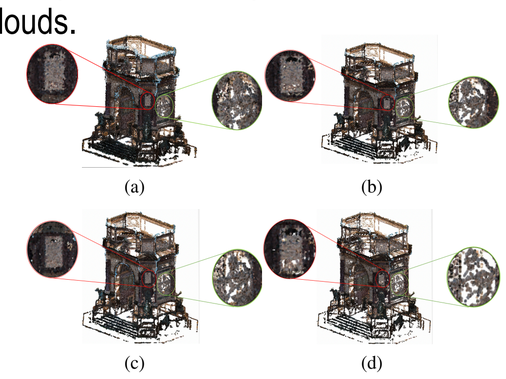

Figure 4: Arco_Valentino model: (a) noisy input, (b) outlier-free input, denoised results by (c) proposed algorithm (d) geometry only graph.

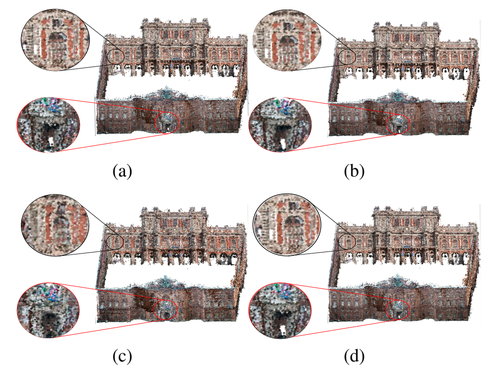

Figure 5: Palazzo_Carignano model: (a) noisy input, (b) outlier-free input, denoised results by (c) proposed algorithm (d) geometry only graph.

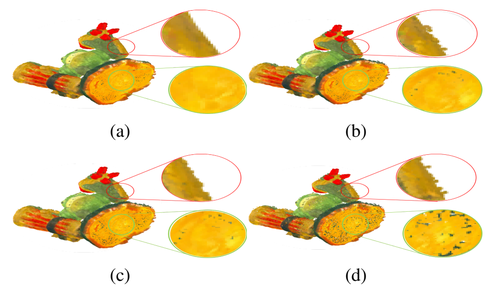

Figure 6: Green_monster model: (a) noisy input, (b) outlier-free input, denoised results by (c) proposed algorithm (d) geometry only graph.

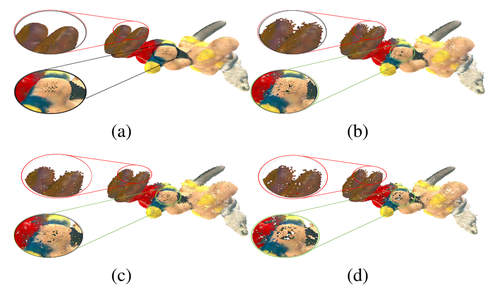

Figure 7: Asterix model: (a) noisy input, (b) outlier-free input, denoised results by (c) proposed algorithm (d) geometry only graph.

Point clouds with synthetic noise

- To simulate the presence of noise, 50% of the points in the noise-free point clouds are affected by noise using uniform distribution.
- The comparative analysis of the proposed denoising algorithm with the state-of-the-art technique on synthetic point cloud is shown in Fig. 8.
- MSE and MCD comparison can be seen in Fig. 9 and Fig. 10.

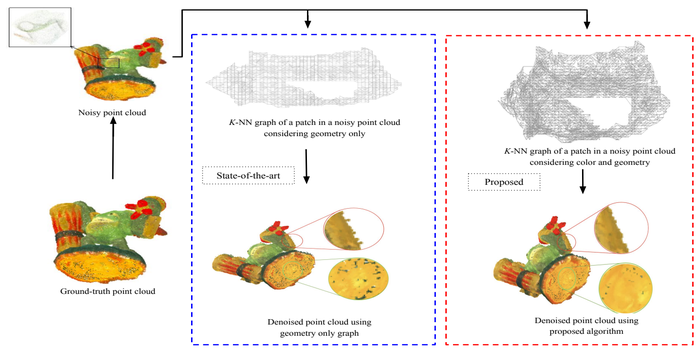

Figure 8: red dotted section represents point cloud denoising using a joint geometry and color graph and blue dotted section represents point cloud denoising using geometry only.

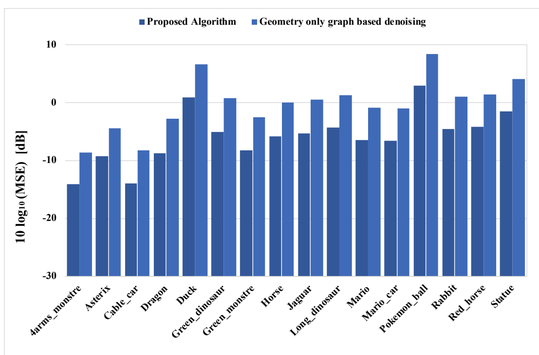

Figure 9: MSE comparison.

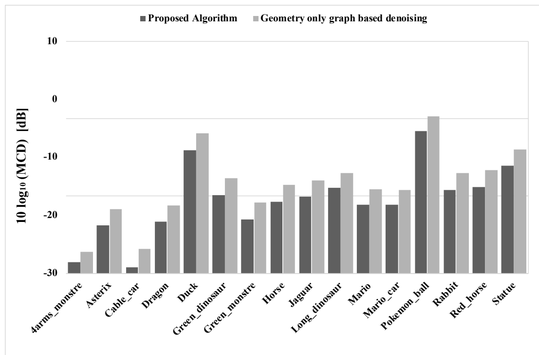

Figure 10: MCD comparison.

List of attended classes

- 01QRQRV – Compressed sensing: theory and applications (30/5/19, 4 credits).
- 01TEVRV – Deep learning (didattica di eccellenza) (4/6/2019, 6 credits).
- 01SFURV – Programmazione scientifica avanzata in matlab (15/5/2019, 4 credits).
- 01QTEIU – Data mining concepts and algorithms (6/3/2018, 4 credits).
- 01QSAIU – Heuristics and metaheuristics for problem solving: new trends and software tools (13/7/2018, 4 credits).
- 08IXTRV – Project management (15/2/2018, 1 credit).
- 01RELKG – Probabilità applicata e machine learning (3/9/2018, 4 credits).
- 01SHCRV – Unsupervised neural networks (didattica di eccellenza) (9/4/2018, 6 credits).
- 02LWHRV – Communication (15/2/2018, 1 credit).
- 01PJMRV – Etica informatica (14/3/2018, 4 credits).
- 01RISRV – Public speaking (15/2/2018, 1 credit).