On the Performance of Temporal Pooling Methods for Quality Assessment of Dynamic Point Clouds

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Summary Of The Presentation

- Dynamic PC Quality Assessment
- LBP Texture Descriptor For PCs
- Temporal Pooling for Quality Assesment
- Experimental Setup
- Results
- Conclusions

Dynamic PC Quality Assessment

Dynamic PC Quality Assessment

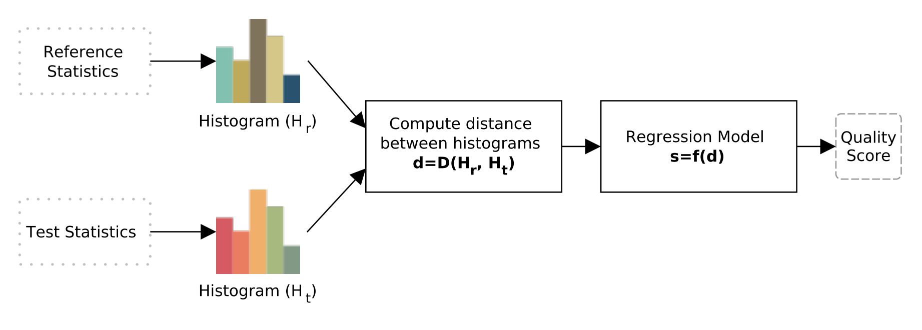
Problem Description

- Dynamic PCs frames contain 3D spatial information (eg. x, y, z), color information (eg. R, G, B) and usually at least 25 fps
- Dynamic PCs present large size when not compressed. Compression is needed for practical storage and transmission
- Realiable DPCQA metrics are needed to estimate the quality of compressed Dynamic PCs, in order the visual content provide a good QoE



LBP Texture Descriptor For PCs

- Use local-neighborhood texture descriptors to estimate the quality of a degraded PC.
- Used for objective full-reference static PCQA

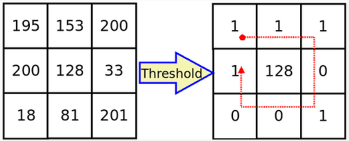


Local Binary Patterns (LBP) for 2D images

$$\mathsf{LBP}_R^N(P_c) = \sum_{n=0}^{N-1} \theta(P_n - P_c) \cdot 2^n,$$

where

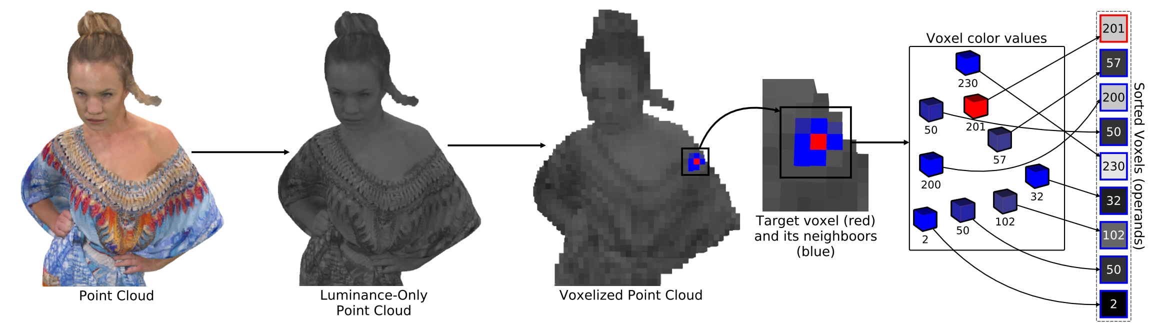
$$\theta(u) = \begin{cases} 1 & \text{if } u \geq 0 \\ 0 & \text{otherwise} \end{cases}$$



- 2D images have pixels equally distributed in a dense 2D grid.

Local Binary Patterns for PC (LBP)

- The LBP is a texture descriptor proposed by Ojala *et al.* to improve the accuracy of texture recognition tasks in 2D images.
- Adaptation of 2D LBP to PCs introduced in a previous work from us
- Different methods can be used to calculate the feature vector distances, for eg., Bray-Curtis, Canberra, Chebyshev, Cityblock, Cosine, Euclidean, Jensen-Shannon, Wasserstein, and Energy.



Temporal Pooling for Quality Assesment

Temporal pooling for 2D video QA already a mature field. This work provides an analysis of different temporal pooling methods for DPCQA.

- N PC frames: $\{f_1, f_2, \cdots, f_N\}$
- N frame-based quality scores $\{q_1, q_2, \cdots, q_N\}$
- Temporal pooling for a overall quality prediction: $Q = F(q_1, q_2, \cdots, q_N)$

Temporal Pooling for Quality Assesment

Different temporal pooling methods available

- Arithmetic, geometric, harmonic means
- Minkowski mean
- Median
- Percentile
- Temporal Variation
- Primacy
- Recency
- Hybrid (Primacy and Recency combination)

Temporal Pooling for Quality Assesment

Two different strategies for its application

- First do the temporal pooling of the features and then calculate the distances
- First calculate the distances and then pool then pool the distances

Experimental Setup

- V-SENSE data-set, containing 2 DPC sequences, in 4 different resolutions, compressed each with 4 different quantization levels
- 4 LPB variants selected for quality estimation of PC frames
- 9 distance metrics: Bray-Curtis (d0), Canberra (d1), Chebyshev (d2), Cityblock (d3), Cosine (d4), Euclidean (d5), Jensen-Shannon (d6), Wasserstein (d7), and Energy (d8).
- Correlation to MOS ground truth: SROCC and PCC

Results

Using strategy 1 - features are first pooled and then distances are calculated (SROCC / PCC)

Descriptor	Pooling	d_0	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8
LBP	Geometric	0.468/0.480	0.407/0.478	-0.549/-0.567	0.580/0.571	0.609/0.603	0.007/-0.039	0.498/0.490	0.591/0.582	0.394/0.415
	Harmonic	0.324/0.364	0.069/0.236	-0.542/-0.563	0.587/0.589	0.618/0.593	0.041/0.003	0.245/0.321	0.595/0.599	0.188/0.203
	Hybrid	0.632/0.614	0.677/0.681	-0.549/-0.572	0.632/0.614	0.633/0.622	-0.038/-0.115	0.668/0.645	0.658/0.619	0.629/0.598
	Mean	0.631/0.616	0.677/0.683	-0.557/-0.573	0.631/0.616	0.636/0.623	-0.038/-0.115	0.667/0.647	0.657/0.621	0.629/0.601
	Median	0.453/0.493	0.410/0.523	-0.548/-0.559	0.459/0.501	0.578/0.565	-0.078/-0.128	0.489/0.495	0.473/0.503	0.440/0.475
	Minkowski	0.751/0.717	0.782/0.790	-0.563/-0.578	0.699/0.671	0.663/0.639	-0.106/-0.178	0.787/0.743	0.705/0.672	0.761/0.713
	Percentile	0.412/0.406	0.036/0.081	-0.384/-0.401	0.800/0.802	**0.667/0.669**	0.302/0.318	0.288/0.296	0.781/0.796	0.090/-0.004
	Primacy	0.440/0.505	0.428/0.536	-0.550/-0.544	0.440/0.505	0.590/0.563	-0.064/-0.143	0.427/0.505	0.428/0.505	0.457/0.485
	Recency	0.552/0.587	0.614/0.655	-0.538/-0.565	0.552/0.587	0.622/0.610	0.015/-0.132	0.579/0.621	0.552/0.592	0.543/0.570
	Up-perc	0.790/0.785	**0.846/0.841**	-0.706/-0.688	0.630/0.604	0.626/0.610	-0.577/-0.589	**0.793/0.798**	0.672/0.634	**0.803/0.786**
	Variation	**-0.810/-0.823**	0.056/0.087	**-0.869/-0.894**	**-0.848/-0.851**	-0.622/-0.644	**-0.885/-0.881**	0.279/0.301	**-0.850/-0.852**	-0.659/-0.740
LBP_u	Geometric	0.330/0.389	0.201/0.209	0.549/0.543	0.392/0.416	0.459/0.446	0.388/0.398	0.356/0.380	0.652/0.643	0.823/0.795
	Harmonic	0.333/0.379	0.233/0.267	0.528/0.506	0.419/0.435	0.442/0.426	0.354/0.379	0.363/0.387	0.653/0.649	0.780/0.762
	Hybrid	0.358/0.400	0.115/0.134	0.596/0.576	0.358/0.400	0.481/0.467	0.425/0.417	0.365/0.379	0.658/0.631	0.813/0.782
	Mean	0.366/0.402	0.121/0.137	0.610/0.578	0.366/0.402	0.486/0.469	0.437/0.418	0.374/0.382	0.658/0.632	0.813/0.783
	Median	0.261/0.298	0.005/0.051	0.472/0.475	0.260/0.305	0.307/0.343	0.304/0.331	0.278/0.283	0.668/0.644	0.777/0.752
	Minkowski	0.409/0.423	0.111/0.085	0.629/0.610	0.384/0.399	0.502/0.498	0.472/0.440	0.411/0.389	0.619/0.599	0.757/0.750
	Percentile	0.093/0.075	0.145/0.125	-0.051/0.003	0.485/0.488	0.209/0.154	0.155/0.119	0.357/0.322	0.585/0.621	0.463/0.493
	Primacy	0.299/0.307	0.110/0.012	0.515/0.511	0.299/0.307	0.405/0.370	0.346/0.348	0.299/0.288	0.624/0.604	0.781/0.751
	Recency	0.361/0.369	0.120/0.090	0.557/0.557	0.361/0.369	0.435/0.430	0.402/0.394	0.339/0.351	0.665/0.636	0.791/0.772
	Up-perc	0.643/0.632	0.072/0.029	0.636/0.654	0.515/0.493	**0.702/0.690**	0.580/0.558	0.525/0.518	0.298/0.333	0.458/0.447
	Variation	**-0.864/-0.869**	**-0.846/-0.915**	**-0.887/-0.862**	**-0.886/-0.872**	-0.431/-0.467	**-0.892/-0.868**	**-0.720/-0.778**	**-0.889/-0.875**	**-0.876/-0.881**

Results

Using strategy 2 - distances are computed first, then the distances are pooled (SROCC / PCC)

Descriptor	Pooling	d_0	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8
LBP	Geometric	0.651/0.630	0.661/0.667	-0.542/-0.564	0.651/0.630	0.635/0.614	-0.081/-0.147	0.638/0.624	0.670/0.645	0.632/0.614
	Harmonic	0.679/0.662	0.694/0.686	-0.538/-0.555	0.679/0.662	0.661/0.633	-0.041/-0.112	0.668/0.656	0.701/0.684	0.659/0.649
	Hybrid	0.605/0.595	0.629/0.628	-0.549/-0.572	0.605/0.595	0.607/0.594	-0.107/-0.183	0.588/0.590	0.635/0.604	0.609/0.576
	Mean	0.604/0.598	0.635/0.632	-0.557/-0.573	0.604/0.598	0.607/0.595	-0.113/-0.183	0.602/0.593	0.641/0.607	0.612/0.579
	Median	0.451/0.493	0.429/0.525	-0.534/-0.555	0.451/0.493	0.599/0.567	-0.168/-0.194	0.511/0.496	0.466/0.495	0.468/0.481
	Minkowski	0.578/0.566	0.599/0.597	-0.569/-0.583	0.578/0.566	0.576/0.576	-0.148/-0.218	0.562/0.561	0.574/0.569	0.591/0.544
	Percentile	0.789/0.831	**0.834**/0.846	-0.376/-0.404	0.789/0.831	0.760/0.761	0.413/0.371	**0.817**/0.838	0.813/0.842	0.799/0.830
	Primacy	0.436/0.474	0.390/0.483	-0.550/-0.544	0.436/0.474	0.573/0.537	-0.136/-0.205	0.404/0.459	0.430/0.484	0.441/0.455
	Recency	0.530/0.560	0.558/0.595	-0.538/-0.565	0.530/0.560	0.589/0.581	-0.077/-0.197	0.510/0.563	0.531/0.572	0.517/0.543
	Up-perc	0.052/0.044	-0.154/0.009	-0.721/-0.699	0.052/0.044	0.430/0.402	-0.545/-0.576	0.027/0.010	0.040/0.045	0.034/0.048
	Variation	**-0.817/-0.841**	-0.815/**-0.850**	**-0.855/-0.879**	**-0.817/-0.841**	**-0.769/-0.789**	**-0.873/-0.875**	-0.816/**-0.853**	**-0.834/-0.853**	**-0.842/-0.855**
LBP_u	Geometric	0.452/0.445	0.168/0.067	0.566/0.544	0.452/0.445	0.505/0.488	0.473/0.436	0.354/0.365	0.735/0.724	0.775/0.746
	Harmonic	0.489/0.497	0.188/0.109	0.600/0.577	0.489/0.497	0.599/0.585	0.500/0.481	0.428/0.405	0.738/0.731	0.775/0.750
	Hybrid	0.348/0.384	0.141/0.026	0.523/0.509	0.348/0.384	0.361/0.376	0.372/0.385	0.280/0.322	0.729/0.717	0.771/0.743
	Mean	0.356/0.387	0.128/0.027	0.523/0.511	0.356/0.387	0.377/0.379	0.378/0.387	0.280/0.324	0.729/0.717	0.771/0.743
	Median	0.257/0.300	-0.011/-0.039	0.476/0.458	0.257/0.300	0.292/0.337	0.279/0.322	0.268/0.279	0.709/0.700	0.760/0.719
	Minkowski	0.294/0.325	0.066/-0.011	0.484/0.478	0.294/0.325	0.263/0.266	0.299/0.336	0.263/0.283	0.715/0.711	0.772/0.739
	Percentile	0.756/0.772	0.617/0.622	0.790/0.795	0.756/0.772	0.767/0.785	0.769/0.763	0.725/0.720	**0.842/0.838**	**0.805/0.844**
	Primacy	0.290/0.292	0.060/-0.051	0.443/0.444	0.290/0.292	0.333/0.287	0.318/0.319	0.259/0.236	0.722/0.688	0.753/0.720
	Recency	0.334/0.355	0.097/0.004	0.482/0.488	0.334/0.355	0.355/0.333	0.360/0.362	0.272/0.294	0.751/0.722	0.732/0.743
	Up-perc	-0.306/-0.303	-0.396/-0.479	0.057/0.074	-0.306/-0.303	-0.285/-0.298	-0.192/-0.197	-0.224/-0.242	0.615/0.591	0.666/0.639
	Variation	**-0.893/-0.869**	**-0.809/-0.825**	**-0.803/-0.847**	**-0.893/-0.869**	**-0.862/-0.874**	**-0.896/-0.875**	**-0.866/-0.862**	-0.799/-0.791	-0.759/-0.736

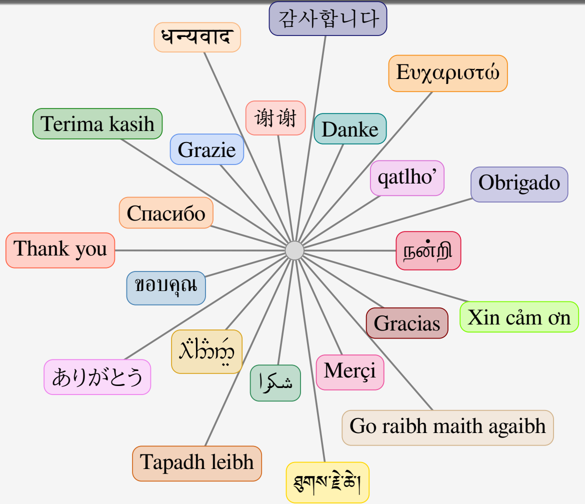
Conclusion

Best SRCCs for Temporal Variation

Descriptor		SRCC d	SRCC Value	SRCC △	PLCC d	PLCC Value	PLCC △
LBP	1	d_5	-0.885	-0.012	d_2	-0.894	-0.015
	2	d_5	-0.873		d_2	-0.879	
LBP_u	1	d_5	-0.892	0.004	d_1	-0.915	-0.040
	2	d_5	-0.896		d_5	-0.875	

- Temporal Variation (Ninassi, 2009)[1] is the best temporal pooling method
- Euclidean (D5) distance performs best
- The proposed method seems to have good results for prediction dynamic PC quality

[1] Ninassi, Alexandre, et al. "Considering temporal variations of spatial visual distortions in video quality assessment." IEEE Journal of Selected Topics in Signal Processing 3.2 (2009): 253-265.



Questions?

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https://gitlab.com/gpds-unb/dpc-temporal-pooling
https://gitlab.com/gpds-unb/pc_metric/