Exploring Spherical Autoencoder for Spherical Video Content Processing

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Why spherical autoencoder?

- 360-degree Video with 3 DoF (Degree of Freedom)
- Widely use in many fields and research areas
- Traditional Video processing:
  - Project frames to 2D content
  - Process with traditional schemes, MPEG
- Spherical autoencoder:
  - Project frames onto 3D mesh content
  - Process with convolution neural network

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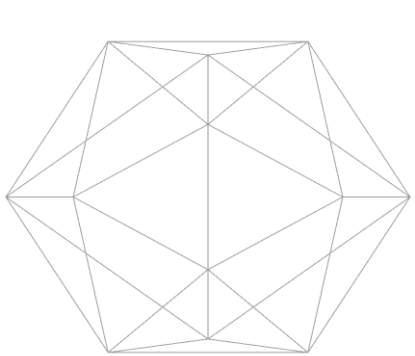
Previous work

Spherical CNN[1]:

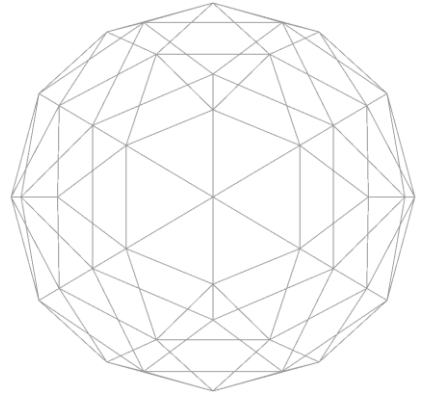
- Lower numbers of network parameters
- Better performance than others

Icosahedral Mesh[2]:

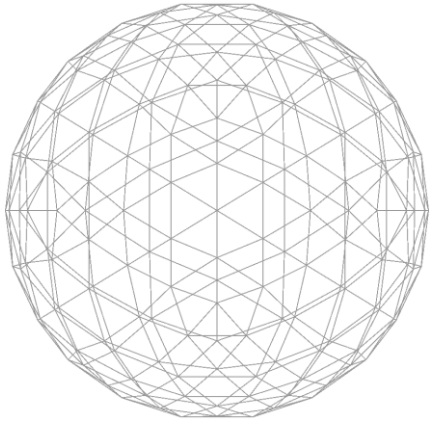
- Discretize use refined icosahedral mesh
- Start with a regular icosahedron
- Divided each faces into 4 smaller faces
- Level-9 mesh contains 2621442 vertices



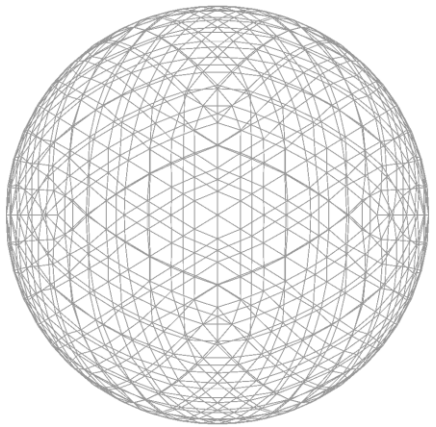
Level-0 mesh



Level-1 mesh



Level-2 mesh



Level-3 mesh

[1] Chiyu" Max" Jiang, et al. "Spherical CNNs on Unstructured Grids." ICLR (Poster). 2019.
[2] Baumgardner, et al. "Icosahedral discretization of the two-sphere." *SIAM Journal on Numerical Analysis* 22.6 (1985)

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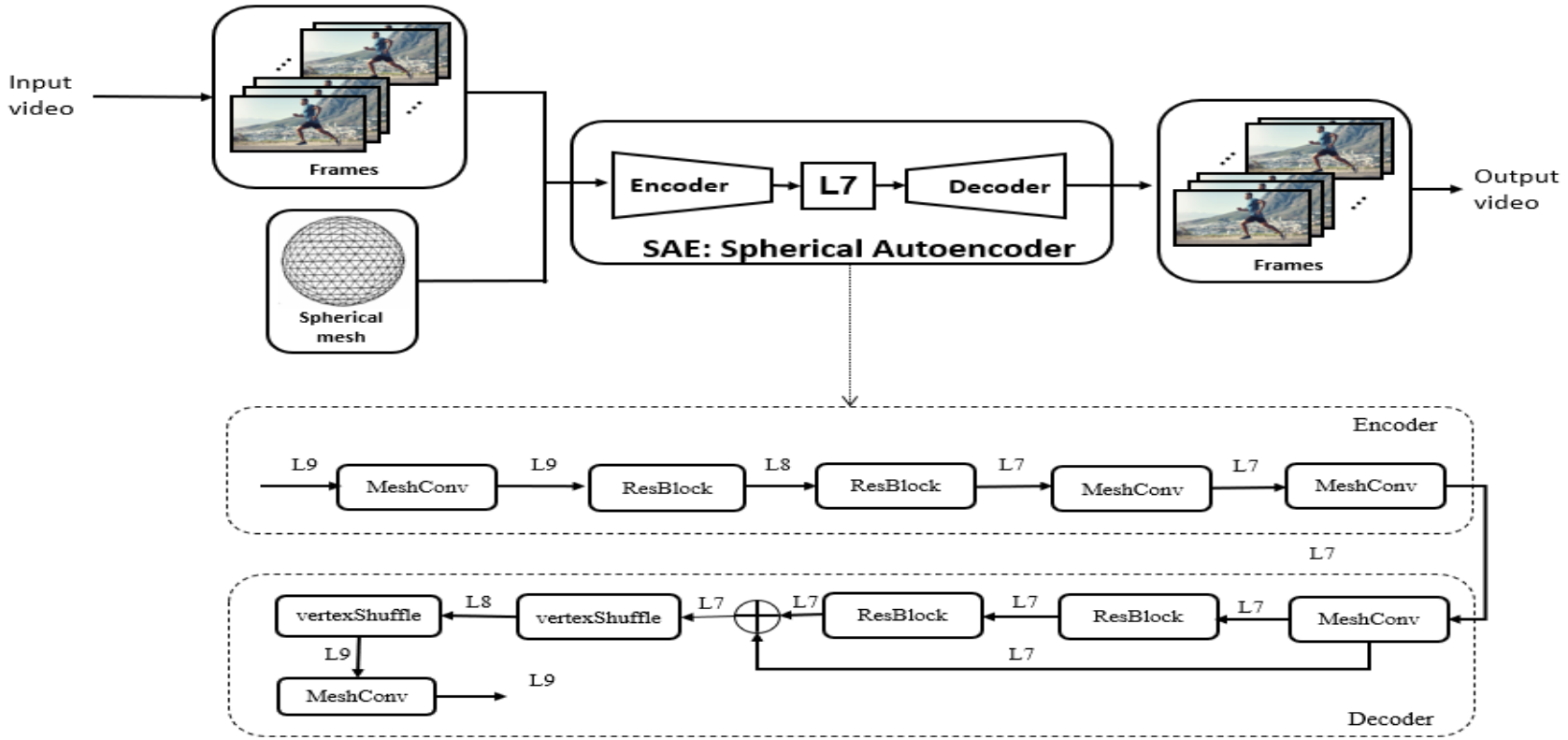
Spherical Autoencoder (SAE)



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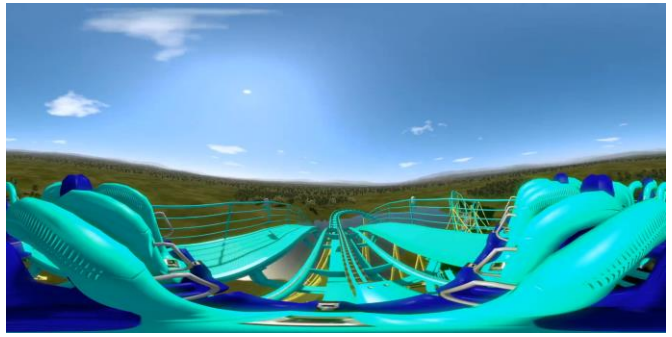
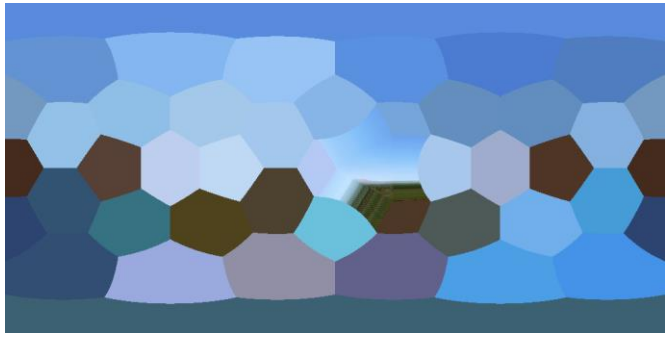
Optimization - Partial Spherical Autoencoder



(a) SAE sample frame



(b) p-SAE sample frame

- Process whole frame each time
- Directly compress it to lower level and use vertexShuffle to recover it.

- Use field-of-view prediction
- Only process 1/80 face each time
- Rotate 79 time to process the whole frame

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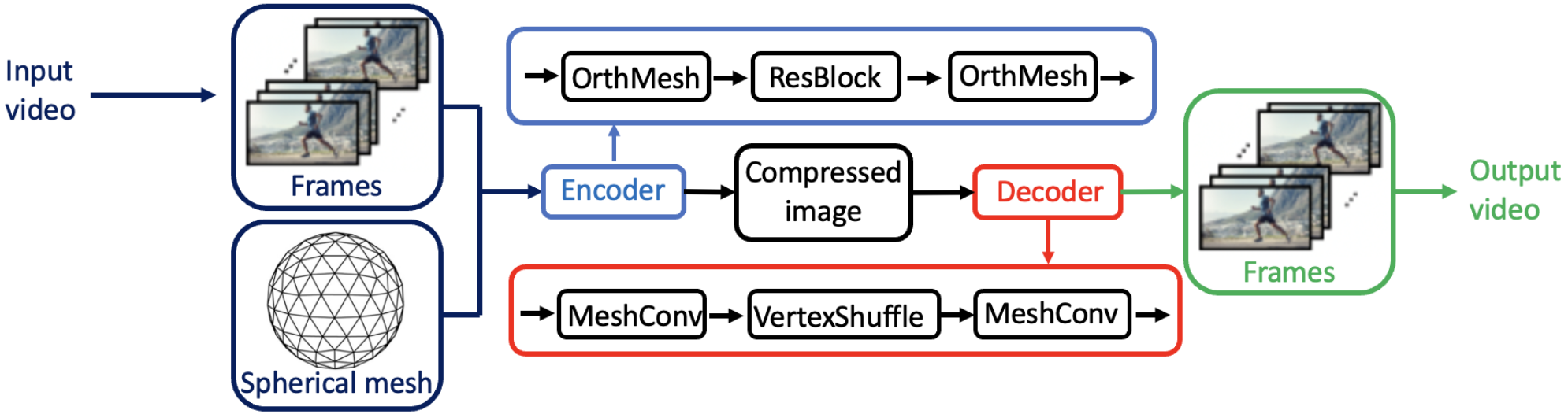
Optimization - Compressive Sensing



- Orthogonal Regularization < Restricted Isometry Property
- Spectral Normalization < Lipschitz continuity

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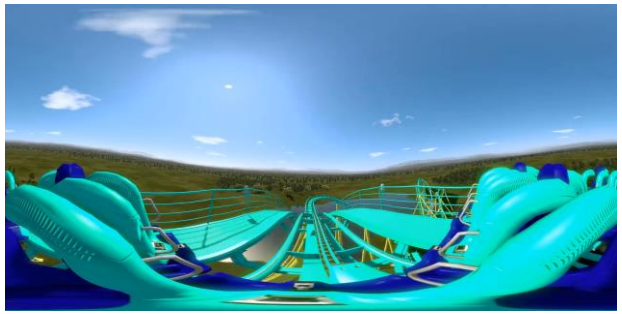
Experiments

- Dataset[1]
  - Highly dynamic, Dynamic, Low motions, Static
  - Different Resolutions：960p, 1080p, 2k, 4k
- Baseline model:
  - 2d Convolutional autoencoder
- Evaluation methods :
  - PSNR, model size, VI-VMAF

(a) classroom



(b) roller-coaster

(c) Indoor

(c) football

[1]These videos are from the “The Psychology of 360-Video” repository, available at https://github.com/vhilab/psych-360

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Result – PSNR

Model	CAE	SAE				p-SAE			
Model Compression Ratio	none	none	26.01%	41.54%	58.30%	none	36.03%	45.97%	55.11%
Indoor	24.7384	39.2887	41.2183	39.0652	38.3835	37.8229	37.7869	36.4909	35.9083
City	17.1524	39.7354	38.9868	38.5078	37.6546	33.4587	33.6031	32.7565	31.8372
Roller-Coaster	17.8414	34.1936	32.8375	32.0299	31.5185	32.5046	32.1746	31.5830	30.3547
Football	20.6538	36.2050	36.3093	36.2165	36.1787	34.4323	33.9375	33.7339	33.2091
Model	co-CAE	c-SAE				c-p-SAE			
Model Compression Ratio	37.21%	none	26.01%	41.54%	58.30%	none	36.03%	45.97%	55.11%
Indoor	20.1124	40.5602	41.3595	39.7724	38.7182	38.6803	38.5517	37.6399	37.5349
City	15.0681	40.3514	39.4804	39.1991	38.9915	34.5360	36.4247	33.6042	33.0823
Roller-Coaster	13.5168	35.5432	33.8656	33.4480	32.6312	33.2020	32.2679	32.1994	31.0052
Football	14.8910	35.5992	36.8822	36.4333	36.0842	36.6811	36.8463	36.4243	36.1195

- CAE – traditional 2D convolutional autoencoder
- co-CAE – CAE with compressive sensing
- SAE – Spherical autoencoder
- p-SAE – partial mesh in SAE
- c-SAE – Spherical autoencoder with compressive sensing
- c-p-SAE – p-SAE with compressive sensing

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Result – Model Size

Model	CAE	SAE				p-SAE			
Model Compression Ratio	none	none	26.01%	41.54%	58.30%	none	36.03%	45.97%	55.11%
Indoor	34.6512	73.4501	73.2218	72.6442	72.6351	70.4519	70.1362	69.8044	69.2314
City	34.0079	72.7804	72.6419	71.9773	71.0025	70.7577	70.5893	69.7488	69.6832
Roller-Coaster	28.5093	68.1255	68.1238	67.9836	67.4821	66.2091	65.9343	65.4290	65.1028
Football	29.8409	68.8549	68.6027	68.4981	68.0195	67.5121	67.4982	67.0034	66.2105
Model	co-CAE	c-SAE				c-p-SAE			
Model Compression Ratio	37.21%	none	26.01%	41.54%	58.30%	none	36.03%	45.97%	55.11%
Indoor	32.8001	75.8872	75.4571	74.7633	73.8041	72.6344	72.1874	71.0801	70.3342
City	31.5367	75.0090	74.6623	74.1342	73.3103	71.9523	71.6345	70.7638	70.1020
Roller-Coaster	25.0956	71.8376	71.0186	71.0123	70.8327	69.7491	68.4566	68.1483	67.3970
Football	26.7573	72.9037	71.9642	71.6107	70.9362	69.9907	69.6016	69.2106	68.6433

Model	CAE	SAE				p-SAE			
Model Compression Ratio	none	none	26.01%	41.54%	58.30%	none	36.03%	45.97%	55.11%
Model Size (KB)	8600	268	195	154	110	250	180	152	126
GPU Usage	4702	13261	13053	12371	11647	2973	2619	2578	2477
Model	co-CAE	c-SAE				c-p-SAE			
Model Compression Ratio	37.21%	none	26.01%	41.54%	58.30%	none	36.03%	45.97%	55.11%
Model Size (KB)	5400	330	207	174	135	321	202	187	131
GPU Usage	3514	15479	15291	14695	14027	1692	1447	1397	1375

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Conclusion

- Spherical Autoencoder maintains the high quality of compression by projecting 360-degree content onto spherical mesh
- Partial Mesh Autoencoder achieves the low computing power and small size of transition data
- Compressive sensing efficiently and effectively guarantees the compression ratio and video quality

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Thank you!

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