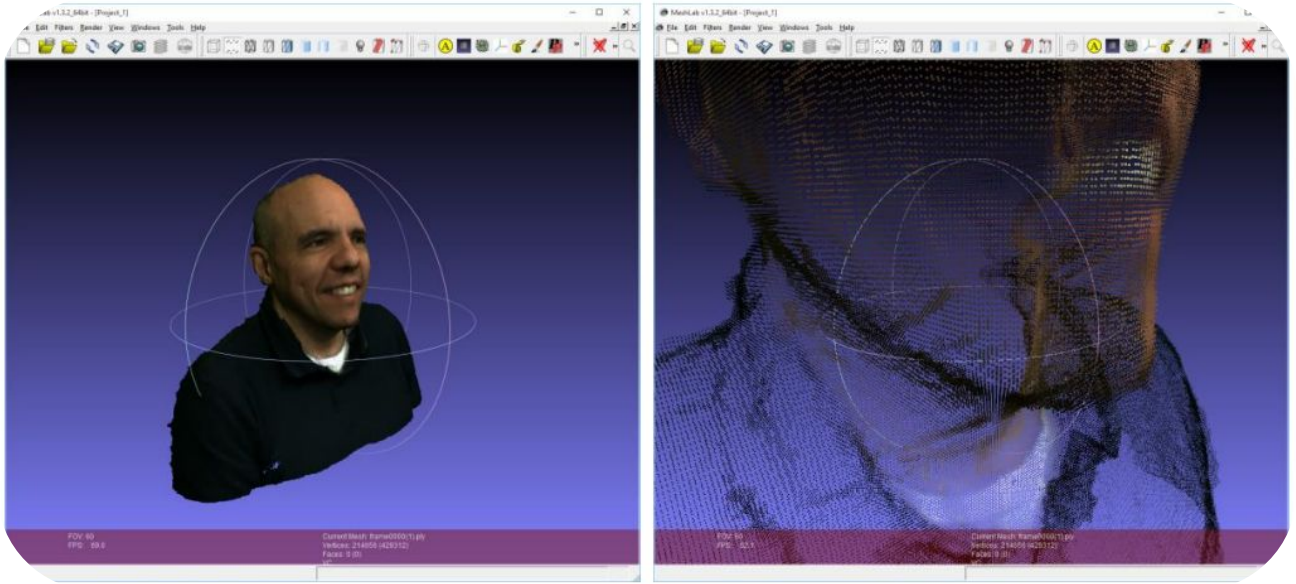
CONTEXT-BASED OCTREE CODING FOR POINT-CLOUD VIDEO

Diogo C. Garcia and Ricardo L. de Queiroz
Universidade de Brasília, Brasil

Summary

1. Point-cloud representation
2. Octree coding
3. Inter-frame octree coding
4. Experiments: testing conditions and results
5. Conclusions

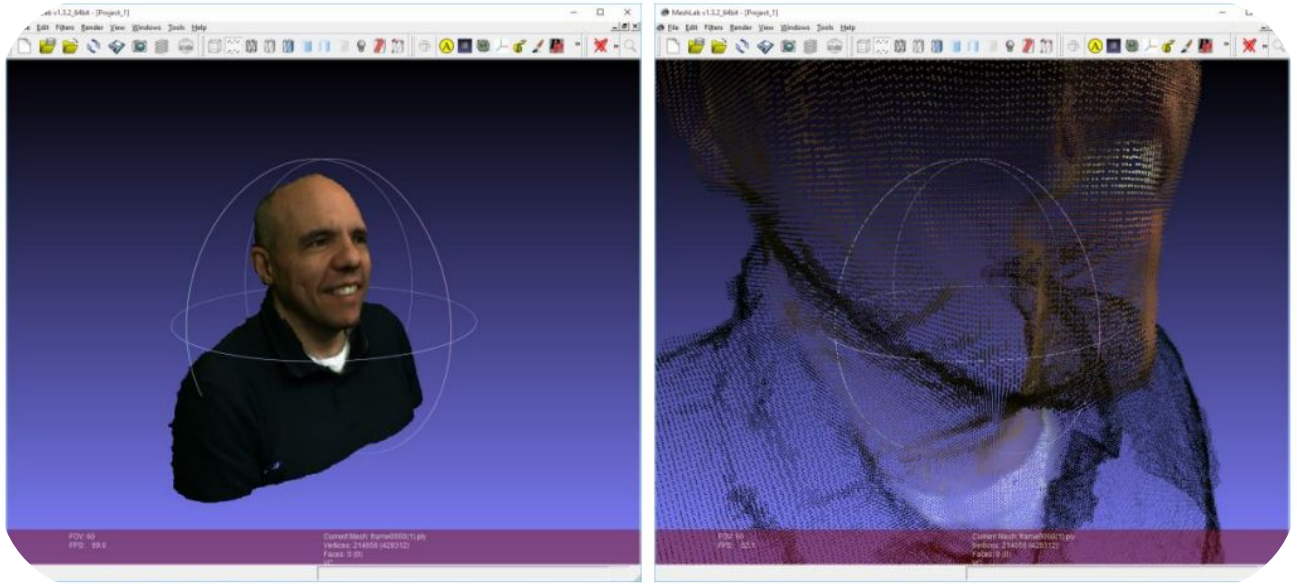
Point-cloud representation



Points in 3D space: voxels

6 atributes per voxel: color + position

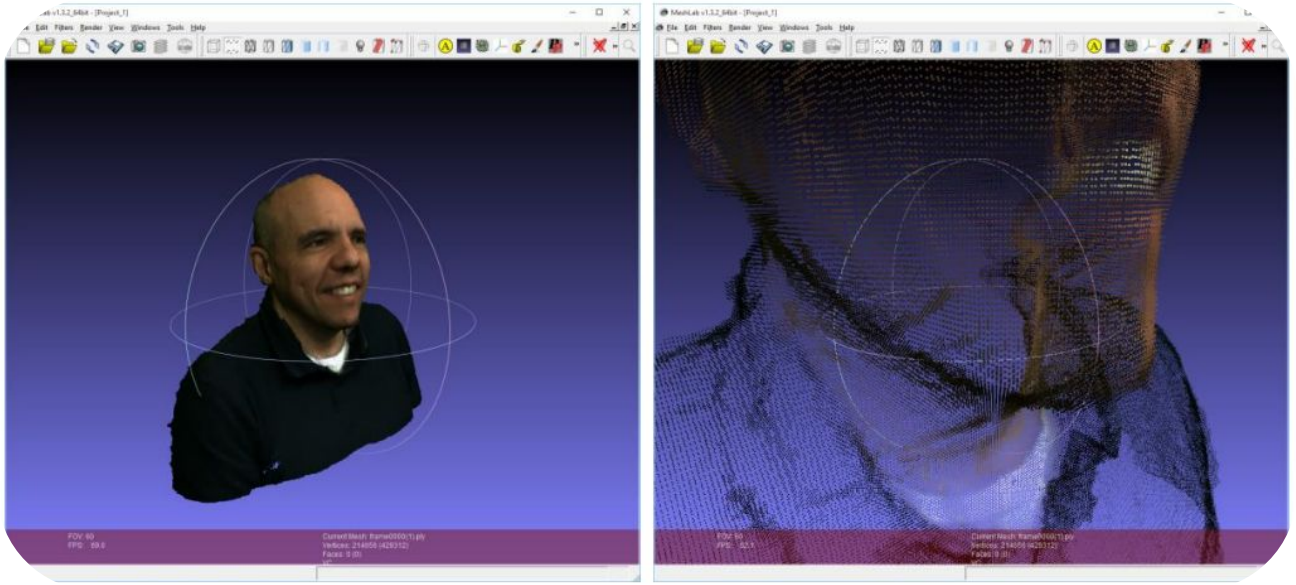
Point-cloud representation



Easier to process in 3D than multiview+depth

Less computationally intensive than polygonal meshes

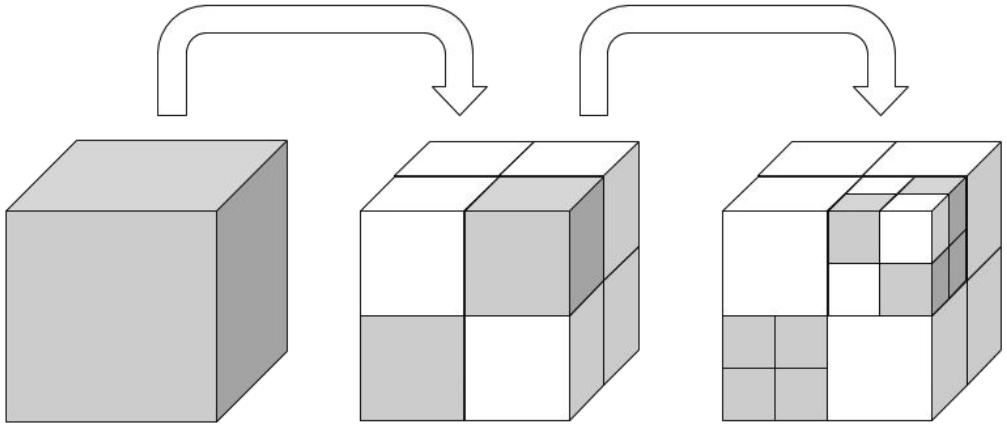
Point-cloud representation



Volumetrically sparse

Requires compression for color and position attributes

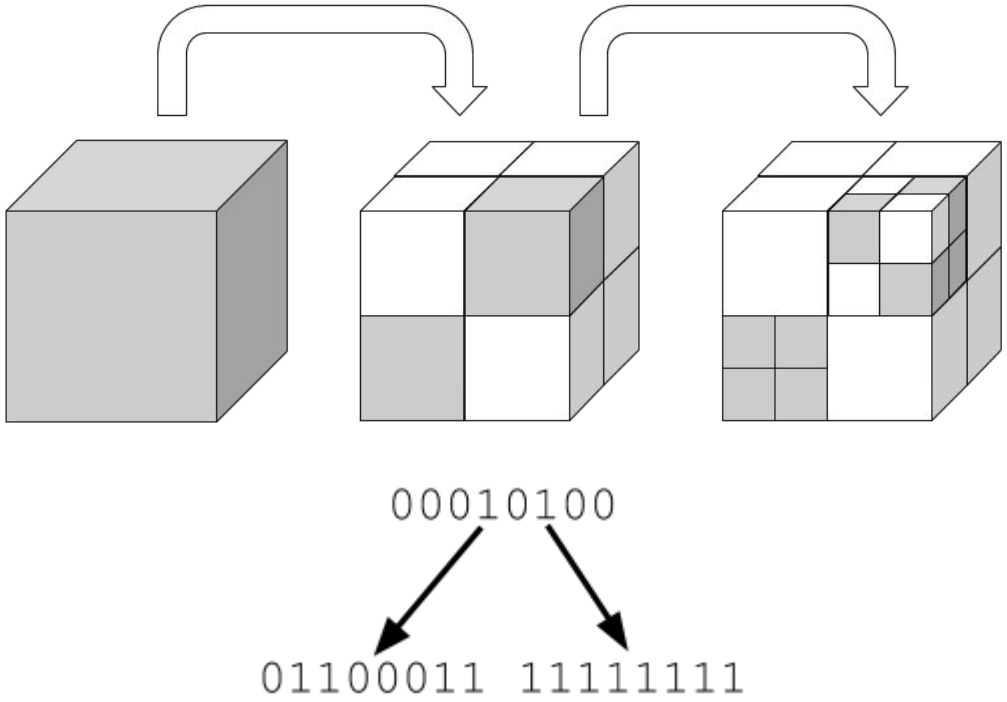
Octree coding



Subdivision of 3D space in octants

Progressive representation

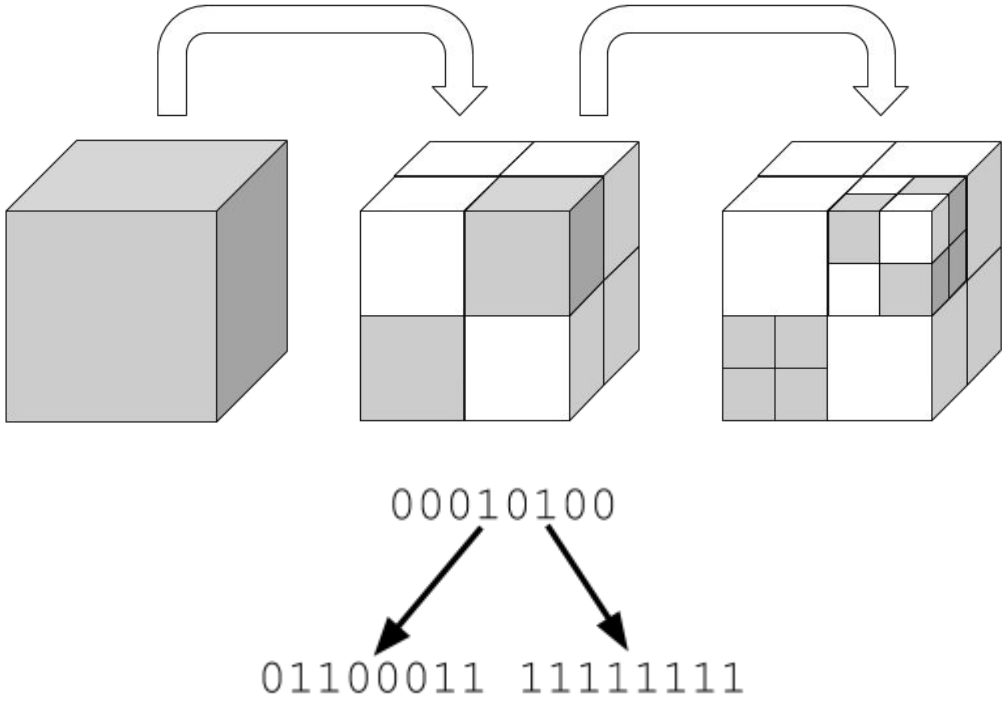
Octree coding



One byte per octant

One bit per occupied octant

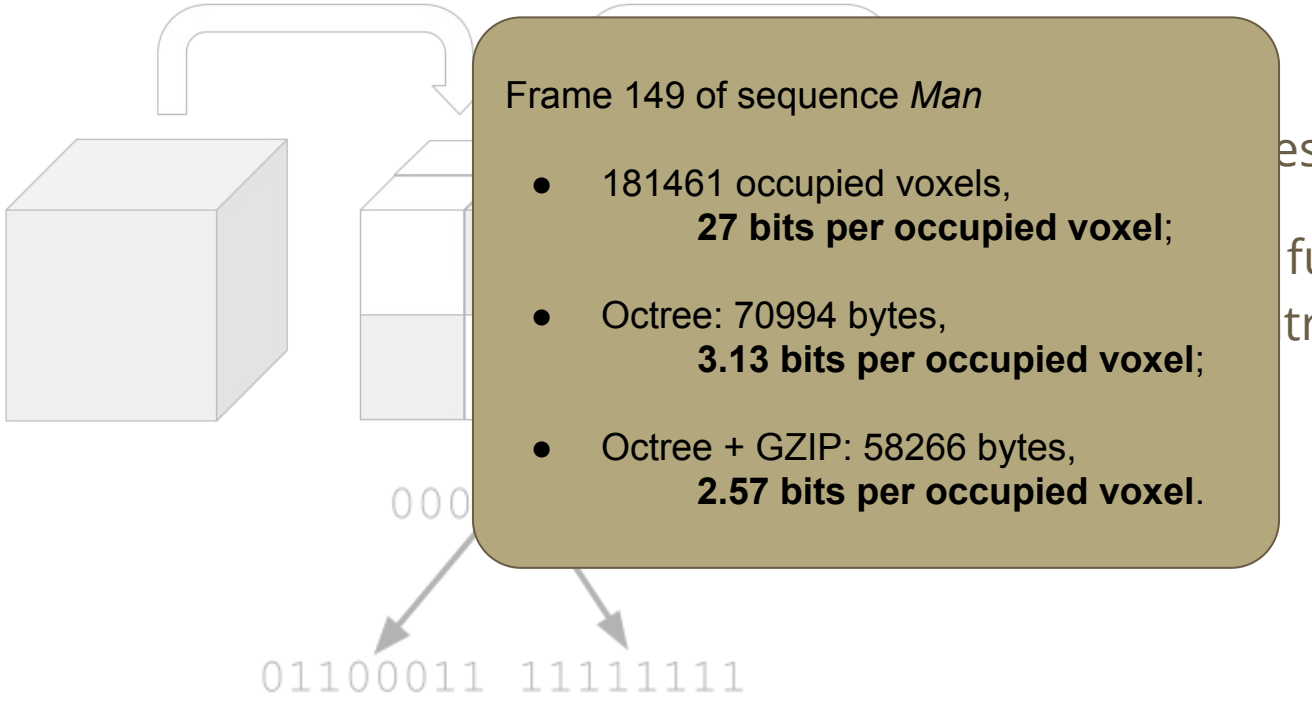
Octree coding



Compresses position data

Can be further compressed with entropy coding

Octree coding



Frame 149 of sequence *Man*

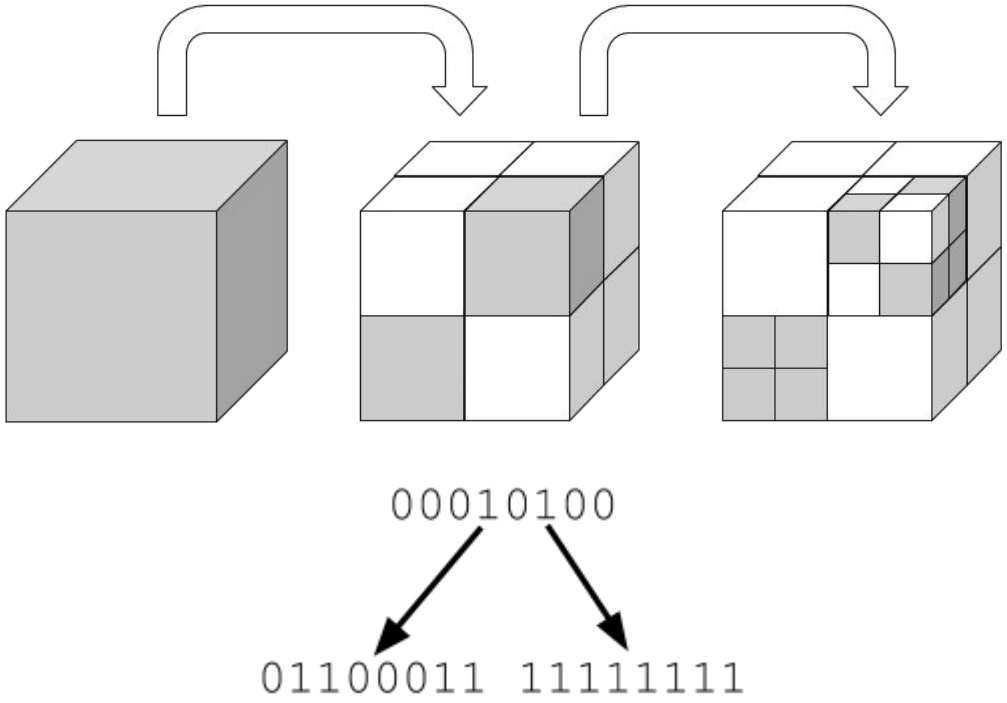
- 181461 occupied voxels,
  27 bits per occupied voxel;
- Octree: 70994 bytes,
  3.13 bits per occupied voxel;
- Octree + GZIP: 58266 bytes,
  2.57 bits per occupied voxel.

esses position data

further compressed

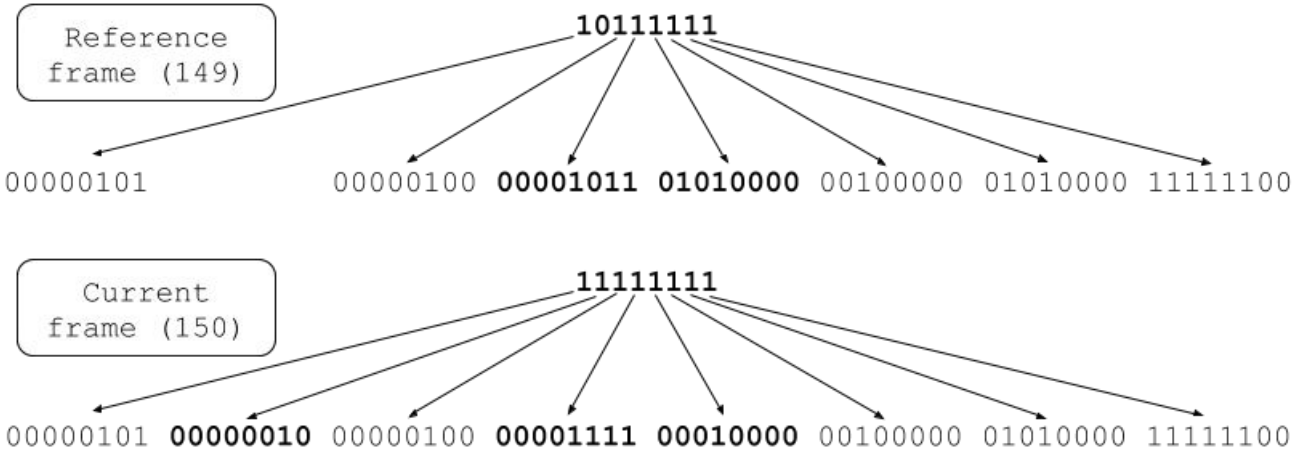
tropy coding

Octree coding



Disregards temporal information (intra coding)

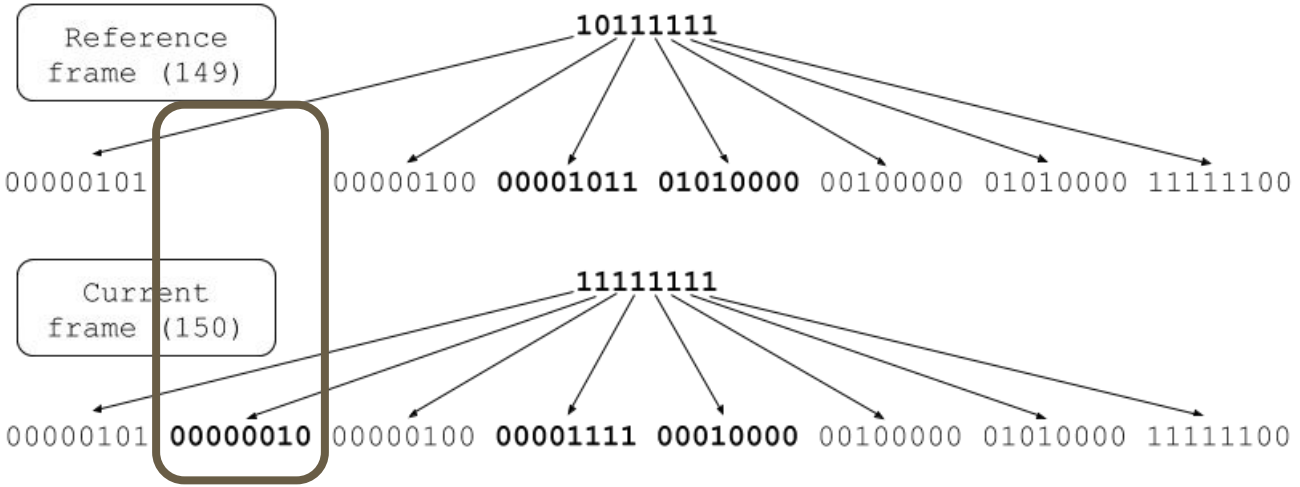
Inter-frame octree coding



Challenges: frames do not share the same

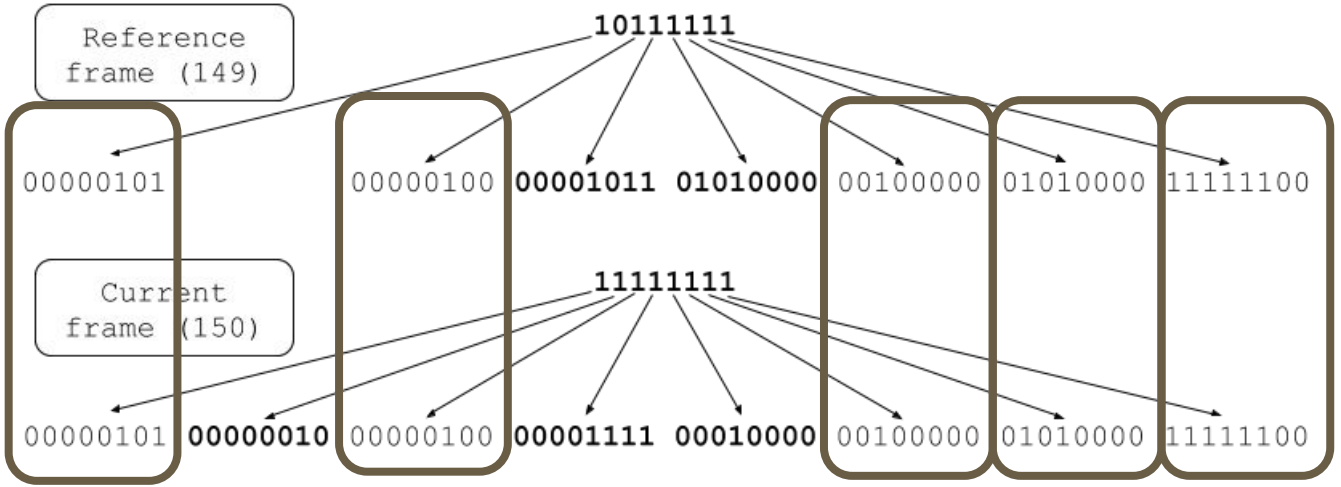
- amount of occupied voxels;
- octree length;
- octants' occupancies.

Inter-frame octree coding



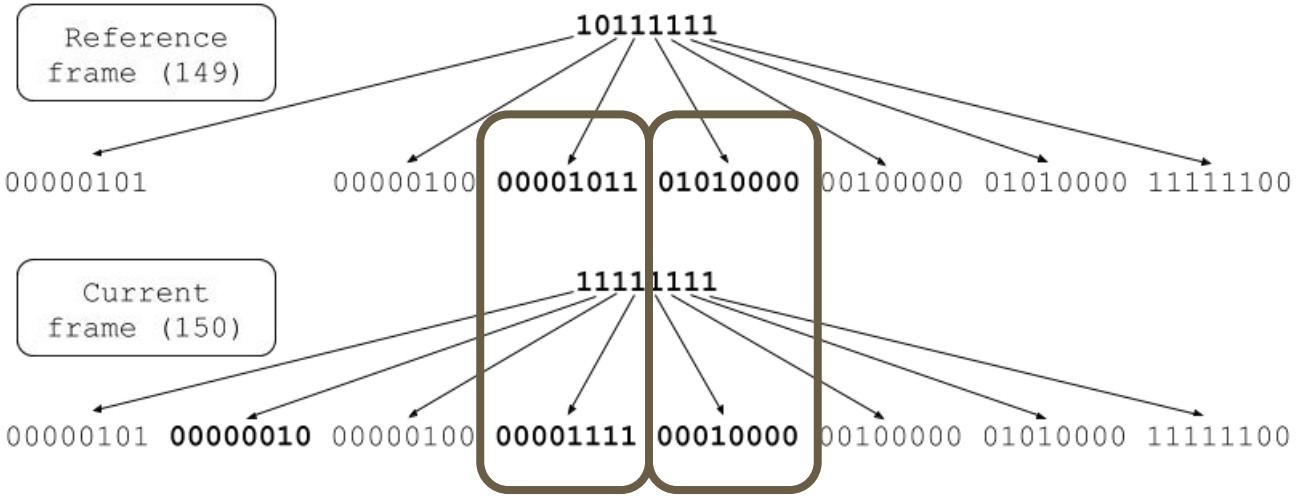
At the first level, the second octant is unoccupied in frame 149, but occupied in frame 150.

Inter-frame octree coding



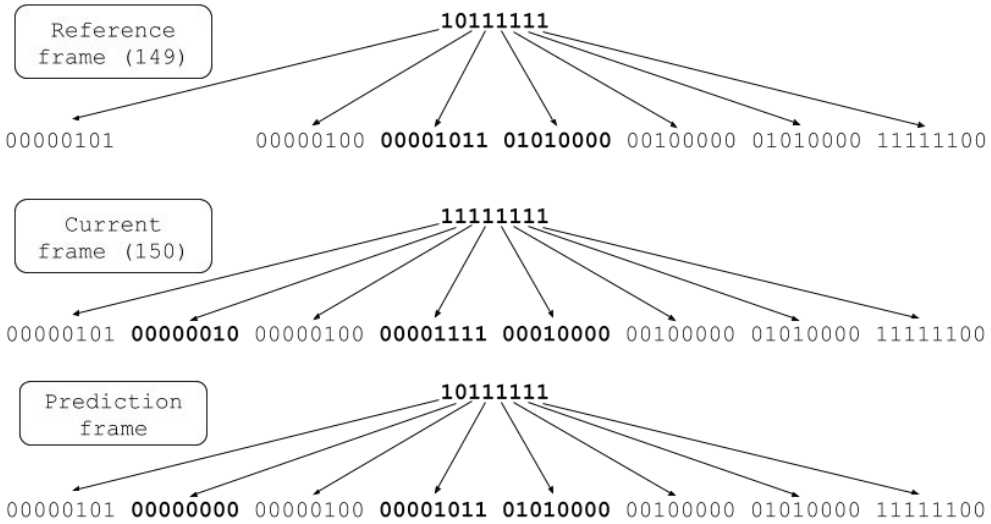
Some levels constitute good predictions

Inter-frame octree coding



Some don't

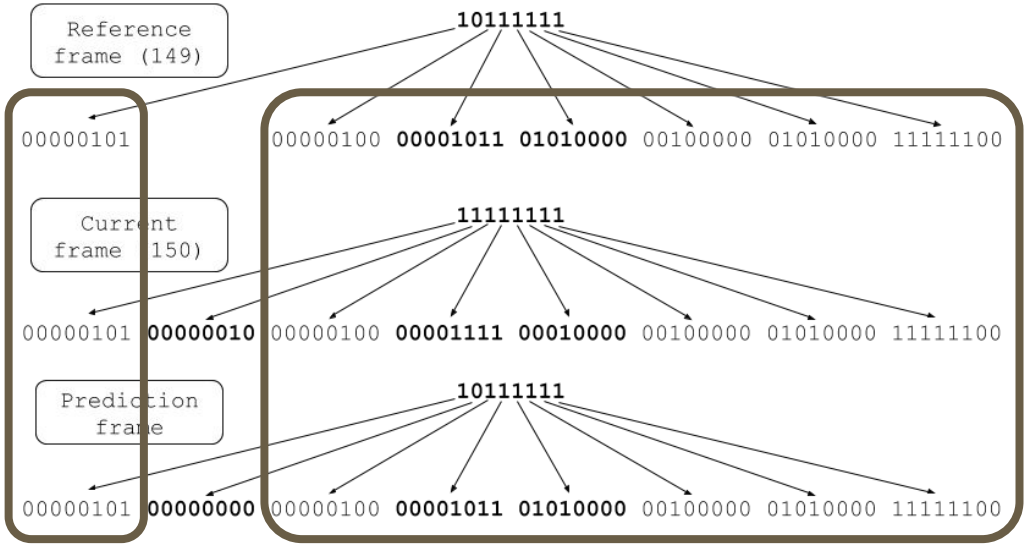
Inter-frame octree coding



Proposed prediction (Kammerl *et. al.*)

- If the same octant is occupied in both reference and current frames, copy reference's sub-octants;
- Otherwise, insert a zero.

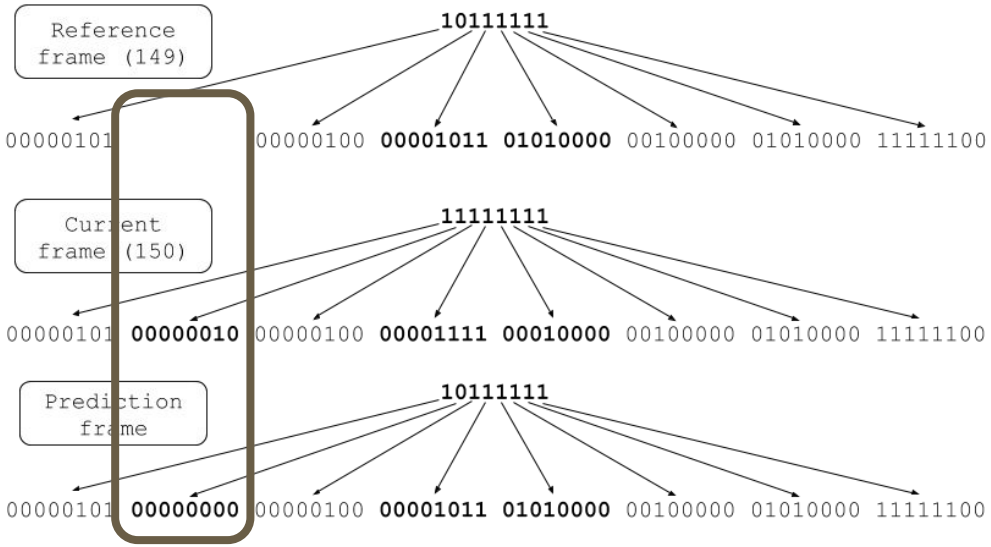
Inter-frame octree coding



Proposed prediction (Kammerl *et. al.*)

- If the same octant is occupied in both reference and current frames, copy reference's sub-octants;
- Otherwise, insert a zero.

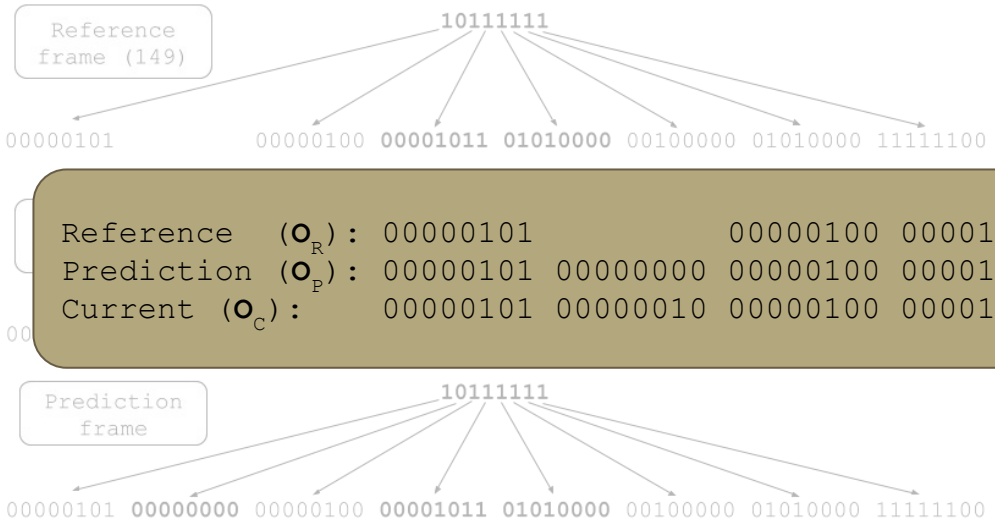
Inter-frame octree coding



Proposed prediction (Kammerl *et. al.*)

- If the same octant is occupied in both reference and current frames, copy reference's sub-octants;
- Otherwise, insert a zero.

Inter-frame octree coding

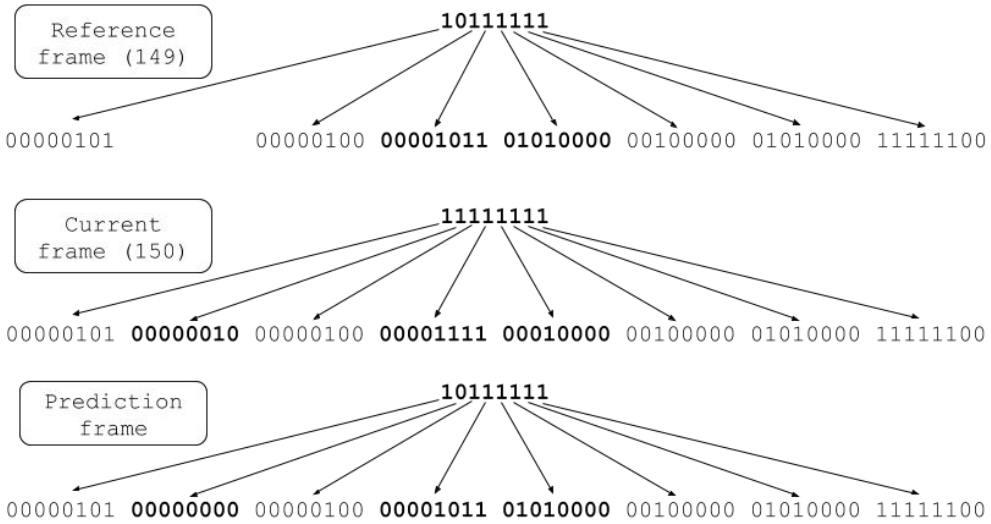



```
Reference  (O_R): 00000101          00000100 00001011 01010000 00100000 01010000 11111100
Prediction (O_P): 00000101 00000000 00000100 00001011 01010000 00100000 01010000 11111100
Current    (O_C):    00000101 00000010 00000100 00001111 00010000 00100000 01010000 11111100
```

Proposed prediction (Kammerl *et. al.*)

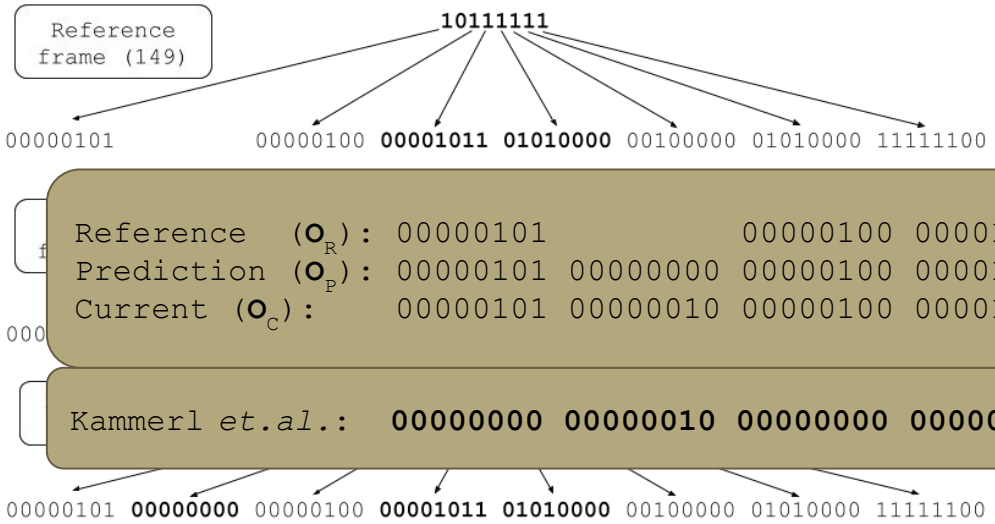
- If the same octant is occupied in
  sub-octants,
- Otherwise, insert a zero.

Inter-frame octree coding



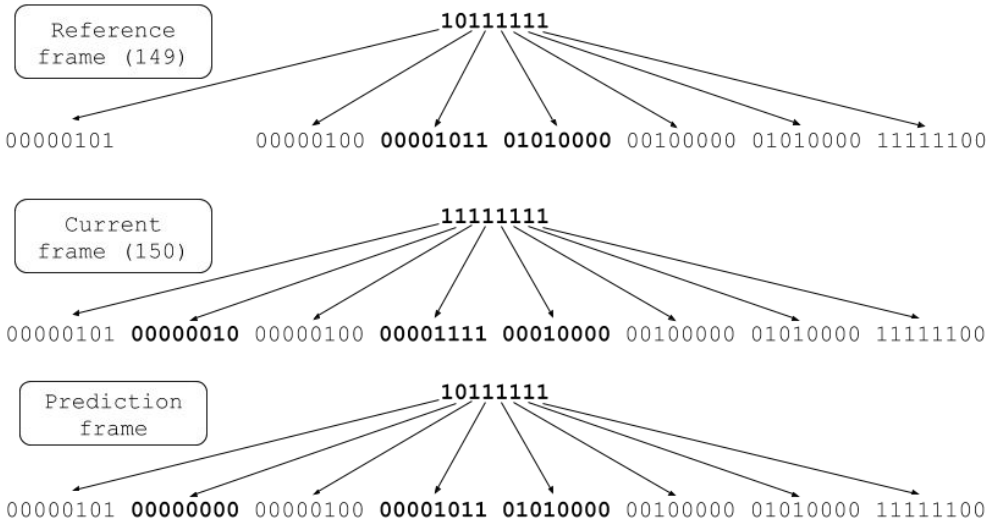
Kammerl *et. al.* entropy-encoded the EXCLUSIVE-OR operation between current and prediction frames: XOR($\mathbf{O}_C$, $\mathbf{O}_P$)

Inter-frame octree coding



Kammerl *et. al.* entropy-encoded the

Inter-frame octree coding



Proposed method

Instead of entropy-encoding

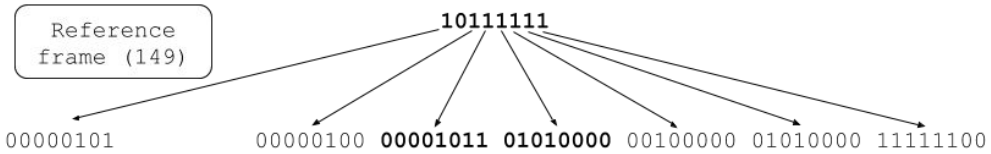
$$\mathrm{XOR}(\mathbf{O}_C, \mathbf{O}_P),$$

$\mathbf{O}_P$ is sorted in ascending order:

$$\mathbf{O}_P \Rightarrow \mathbf{O}_{SP}$$

and the sorting order is applied to $\mathbf{O}_C$, creating $\mathbf{O}_{SC}$, which is entropy-coded.

Inter-frame octree coding



Proposed method

Instead of entropy-encoding

```
Reference  (O_R): 00000101          00000100 00001011 01010000 00100000 01010000 11111100
Prediction (O_P): 00000101 00000000 00000100 00001011 01010000 00100000 01010000 11111100
Current    (O_C):    00000101 00000010 00000100 00001111 00010000 00100000 01010000 11111100
```

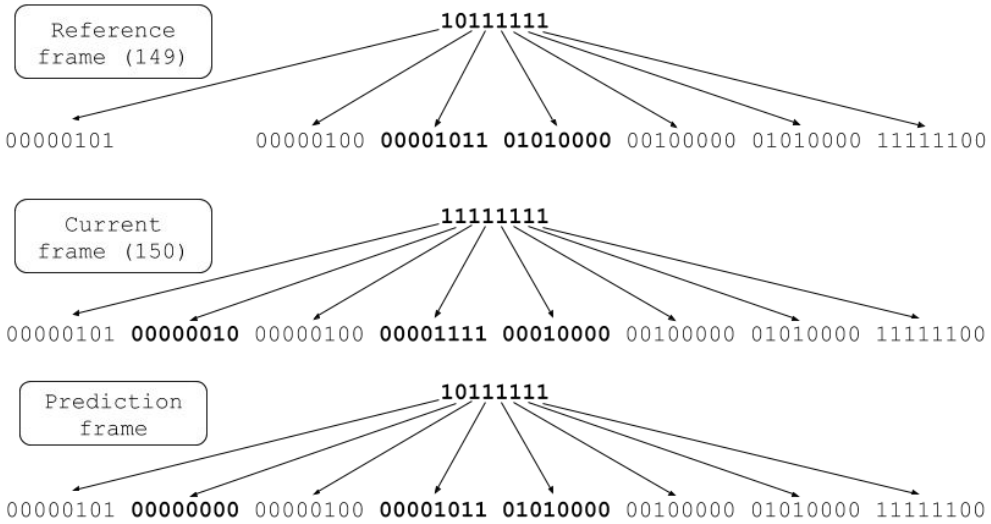
```
Kammerl et.al.:  00000000 00000010 00000000 00000100 01000000 00000000 00000000 00000000
```

```
Sorted O_P (O_SP): 00000000 00000100 00000101 00001011 00100000 01010000 01010000 11111100
Sorted O_C (O_SC): 00000010 00000100 00000101 00001111 00100000 00010000 01010000 11111100
```

$O_{C'}$

creating $O_{SC'}$, which is entropy coded.

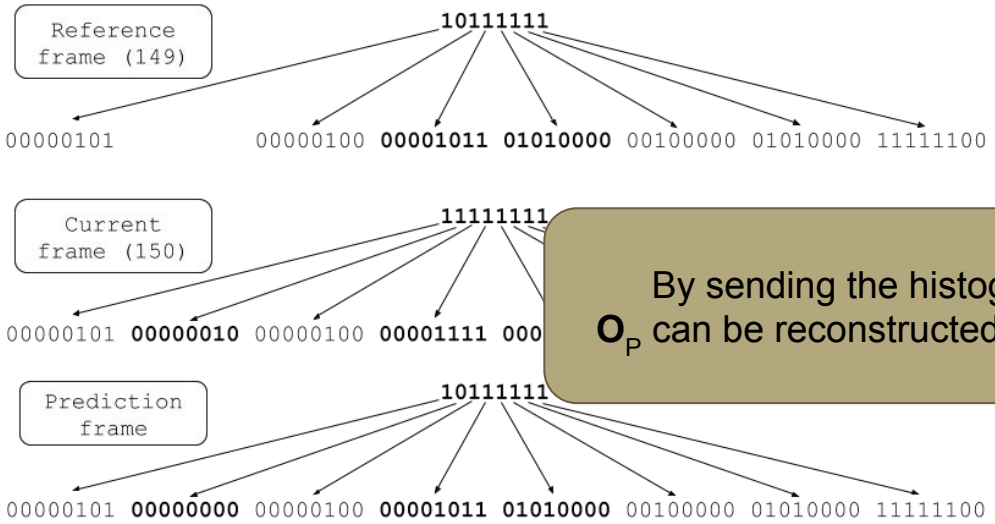
Inter-frame octree coding



If $\mathbf{O}_P$ is a good prediction, $\mathbf{O}_{SP}$ will have long sequences of repeated symbols, and so will $\mathbf{O}_{SC}$.

If $\mathbf{O}_P$ is not a good prediction, $\mathbf{O}_{SC}$ will just be a scrambled version of $\mathbf{O}_{C'}$ with similar statistics and entropy.

Inter-frame octree coding



By sending the histogram of $\mathbf{O}_{SP}$, $\mathbf{O}_{P}$ can be reconstructed at the decoder.

If $\mathbf{O}_{P}$ is a good prediction, $\mathbf{O}_{SP}$ will have long sequences of repeated symbols, and so will $\mathbf{O}_{SC}$.

good prediction, $\mathbf{O}_{SC}$ will mbled version of $\mathbf{O}_{C'}$, with similar statistics and entropy.

Inter-frame octree coding

$$\mathbf{V}_{R1} = \begin{bmatrix} 10 & 10 & 10 \\ 10 & 10 & 12 \\ 11 & 12 & 10 \\ 12 & 13 & 5 \end{bmatrix}, \mathbf{V}_{R2} = \begin{bmatrix} 10 & 10 & 10 \\ 10 & 10 & 12 \\ 11 & 11 & 11 \\ 12 & 13 & 5 \end{bmatrix}$$

$$\mathbf{V}_{R} = \begin{bmatrix} 10 & 10 & 10 \\ 10 & 10 & 12 \\ 11 & 11 & 11 \\ 11 & 12 & 10 \\ 12 & 13 & 5 \end{bmatrix}$$

If there is more than one reference, their union is used as a new reference.

Experiments

First 200 frames of publicly available sequences:

Andrew, *David*, *Man*, *Phil*, *Ricardo* and *Sarah*

Six scenarios:

- **FO**: Full octree;
- **EO**: Entropy-encoded octree;
- **KA**: Entropy-encoded XOR($\mathbf{O}_C$, $\mathbf{O}_P$) (Kammerl *et. al.*);
- **P1**: Proposed method, 1 reference frame;
- **P2**: Proposed method, 2 references frames;
- **P3**: Proposed method, 3 references frames.

Experiments

First 200 frames of publicly available sequences:

Andrew, *David*, *Man*, *Phil*, *Ricardo* and *Sarah*

Six scenarios:

- **FO**: Full octree;
- **EO**: Entropy-encoded octree;
- **KA**: Entropy-encoded XOR($\mathbf{O}_C$, $\mathbf{O}_P$) (Kammerl *et. al.*);
- **P1**: Proposed method, 1 reference frame;
- **P2**: Proposed method, 2 references frames;
- **P3**: Proposed method, 3 references frames.

DEFLATE-based (GZIP) entropy coder for all of them

Experiments

Sequence	FO	EO	KA	P3	P2	P1
Andrew	2.58	1.94	1.83	1.70	1.69	**1.69**
David	2.62	1.89	2.09	1.86	1.85	**1.83**
Man	3.16	2.51	2.48	2.35	2.33	**2.29**
Phil	2.64	2.00	2.13	1.93	1.91	**1.88**
Ricardo	2.92	2.37	2.39	2.24	2.23	**2.22**
Sarah	2.61	1.89	1.92	1.74	1.72	**1.70**
Average	2.76	2.10	2.14	1.97	1.96	**1.94**

Average rate in bits per occupied voxel

- **FO**: Full octree;
- **EO**: Entropy-encoded octree;
- **KA**: Entropy-encoded XOR($\mathbf{O}_C$, $\mathbf{O}_P$) (Kammerl *et. al.*);
- **P1**: Proposed, 1 ref. frame;
- **P2**: Proposed, 2 ref. frames;
- **P3**: Proposed, 3 ref. frames.

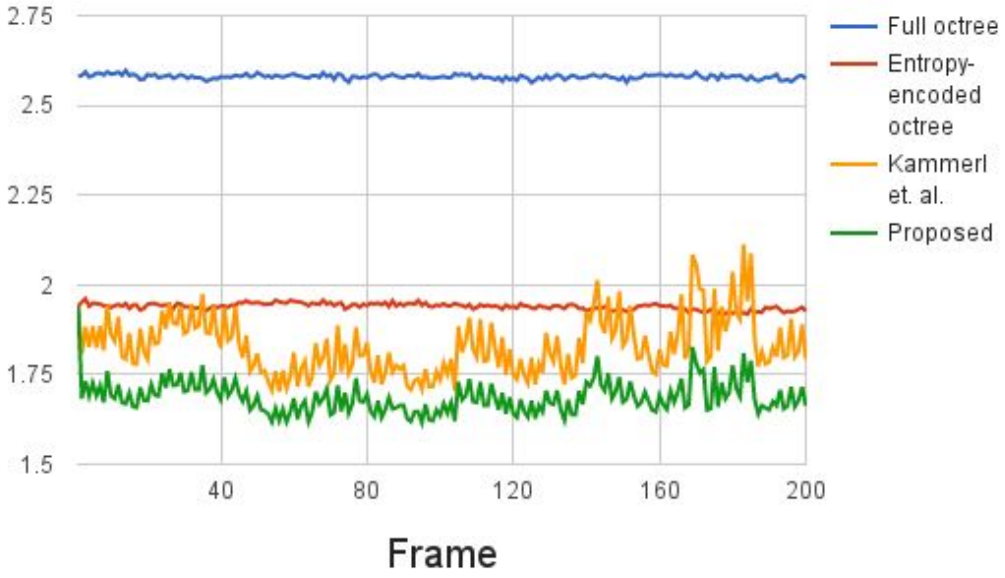
Experiments

Sequence	EO	KA	P3	P2	P1
Andrew	25%	29%	34%	34%	**34%**
David	28%	20%	29%	29%	**30%**
Man	21%	22%	26%	26%	**28%**
Phil	24%	19%	27%	28%	**29%**
Ricardo	19%	18%	23%	24%	**24%**
Sarah	28%	26%	33%	34%	**35%**
Average	24%	22%	29%	29%	**30%**

Average rate gain over full octree

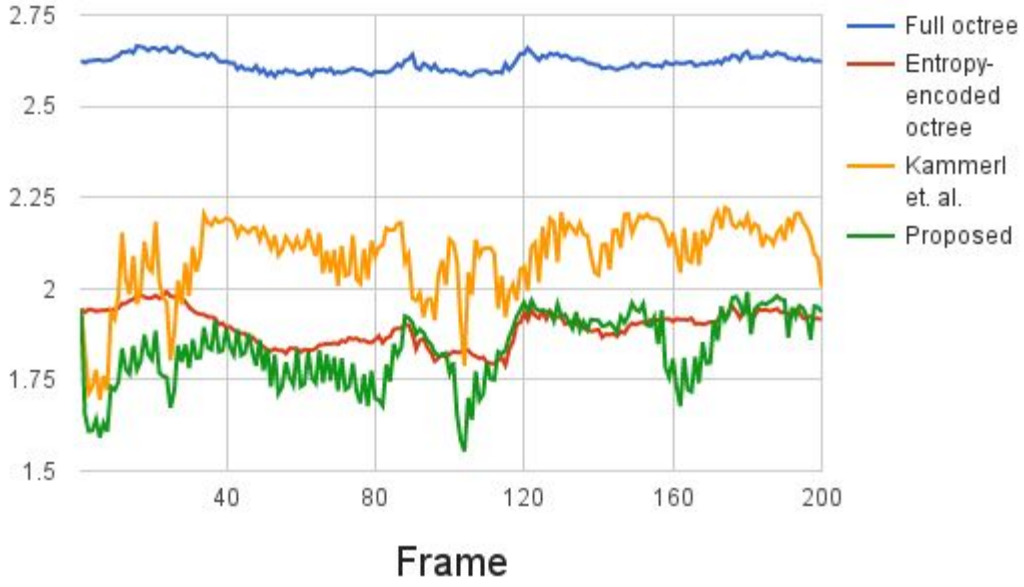
- **EO**: Entropy-encoded octree;
- **KA**: Entropy-encoded XOR($\mathbf{O}_C$, $\mathbf{O}_P$) (Kammerl *et. al.*);
- **P1**: Proposed, 1 ref. frame;
- **P2**: Proposed, 2 ref. frames;
- **P3**: Proposed, 3 ref. frames.

Experiments



Rate on a frame basis, in bits per occupied voxel, for the *Andrew* sequence

Experiments



Rate on a frame basis, in bits per occupied voxel, for the *David* sequence

Conclusions

- Lossless inter-frame compression method for point-cloud geometry;
- Better than entropy-encoding the octree;
- Better than XORing a prediction and entropy-encoding;
- Further improvements:
  - Motion estimation and compensation;
  - Test other entropy-coding methods.