# Compression of Mesh Sequences

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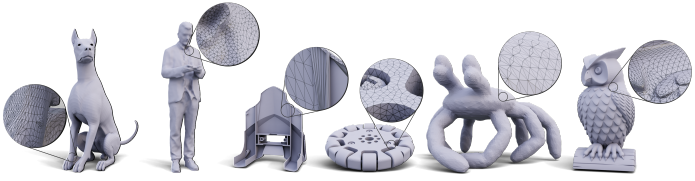
November 15, 2024



# Context

## Motivation

Necessary for **storing**, **transmitting**, and **processing** large volumes of data.

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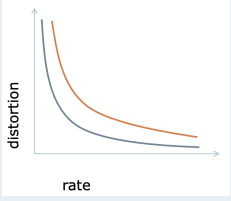
## Lossy Compression

- essential for data intended for human observers
- usually **significantly more efficient** than lossless
- more complex evaluation - RD curve



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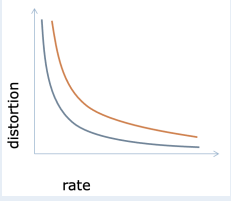
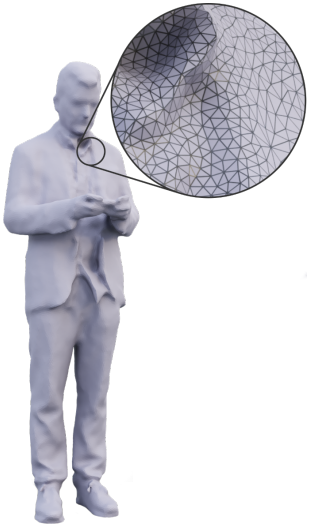



## Compression in Computer Graphics

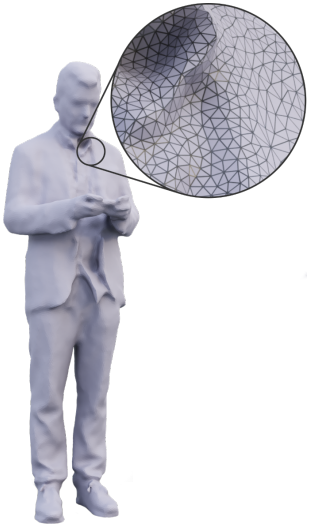
Fundamentally important because
**details = realism**

# Triangle Meshes





- widely used in industry: entertainment, film, ...
- represent the **shape** of an object



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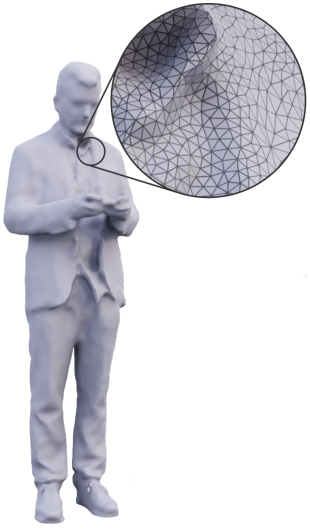
## Geometry

- vertex **coordinates**
- triplets of floating point numbers

$$\mathcal{G} = \{[x_i, y_i, z_i]\}_{i=0}^{V-1}$$



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## Connectivity

- represents **triangles**
- triplets of integers

$$\mathcal{T} = \{[a_i, b_i, c_i]\}_{i=0}^{T-1}$$

# Compression of Mesh Sequences - Constant Connectivity

## Original Approach

express **frames** as a linear combination of a basis

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- can be combined with predictions
  - Parallelogram: $P = L + R - B$
  - Weighted parallelogram: $P = w_1 L + w_2 R - (1 - w_1 - w_2) B$

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  - Parallelogram: $P = L + R - B$
  - Weighted parallelogram: $P = w_1 L + w_2 R - (1 - w_1 - w_2)B$
- data rate $<$ 1bpfv without visible data distortion

Váša, L., & Skala, V. (2007, May). Coddyac: Connectivity driven dynamic mesh compression. In 2007 3DTV Conference (pp. 1-4). IEEE.
Váša, L., & Petřík, O. (2011, August). Optimising perceived distortion in lossy encoding of dynamic meshes. In Computer Graphics Forum (Vol. 30, No. 5, pp. 1439-1449). Oxford, UK: Blackwell Publishing Ltd.

# Compression of Mesh Sequences - Varying Connectivity

## Open Problem

Best results so far achieved by per-frame compression.

Dvořák, J., Hácha, F, Arvanitis, G., Podgorelec, D., Moustakas, K., Váša, L.: A Survey of Inter-Prediction Methods for Time-Varying Mesh Compression, submitted to Computer Graphics Forum, 2024 (2nd revision).

# Compression of Time-Varying Meshes (TVM)



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## Core Problem

Vertex coordinates contain **inseparably**

- information on **sampling** of the surface (no inter-frame coherence)
- information on **shape** of the surface (high inter-frame coherence)

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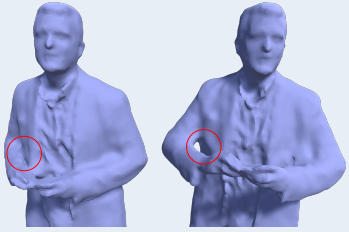
## Research Goal

- extract information on shape and its **development over time**
- use the information in encoding frames

## Surface Correspondence

- Difficult to establish
- Not bijective - contact surfaces



# Correspondence in Mesh Sequences



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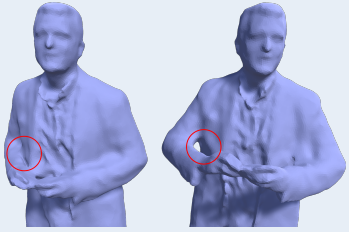


## Correspondence of Volume Elements

- **Bijective** for a wide range of realistic data
- Can be established by optimizing appropriate criteria

Dvořák, J., Vaněček, P., & Váša, L. (2021, June). Towards understanding time-varying triangle meshes. In International Conference on Computational Science (pp. 45-58). Cham: Springer International Publishing.

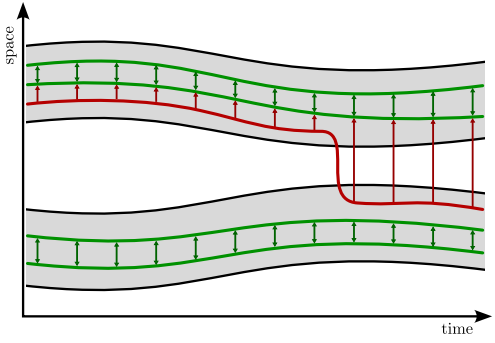
Dvořák, J., Káčereková, Z., Vaněček, P., Hruda, L., & Váša, L. (2022). As-rigid-as-possible volume tracking for time-varying surfaces. Computers & Graphics, 102, 329-338.

# Volume Element Tracking

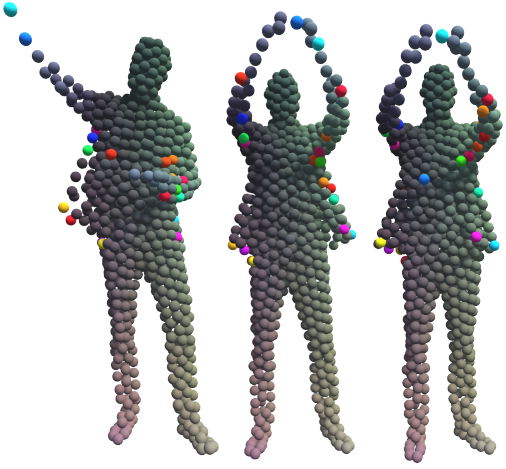


- similarity of trajectories $E_s$
- uniform sampling of the mesh interior $E_u$

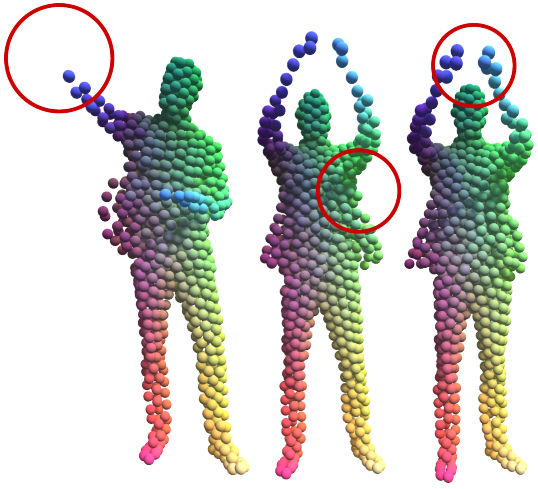
Detect irregularly tracked centers




$$I_i = \min_j \|\mathbf{c}_i - \mathbf{c}_j\|_2^2$$



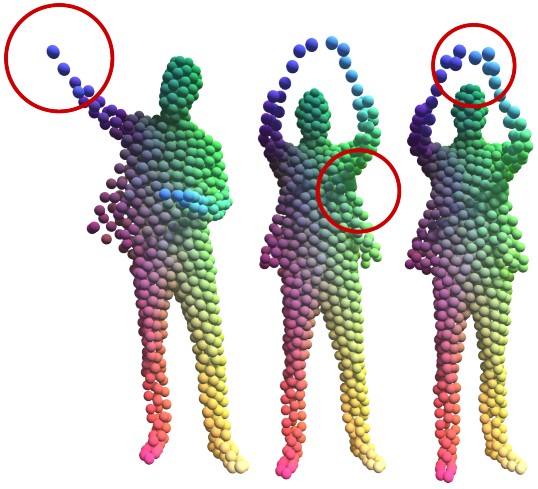
Remove them



Temporally global optimization

$$\hat{E} = \hat{E}_s + \hat{\beta}\hat{E}_u$$

Similar to forward tracking, however, evaluated over all the frames.



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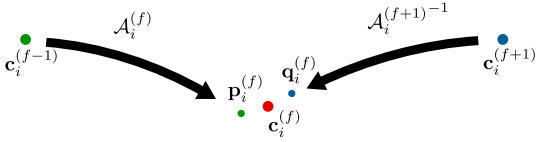
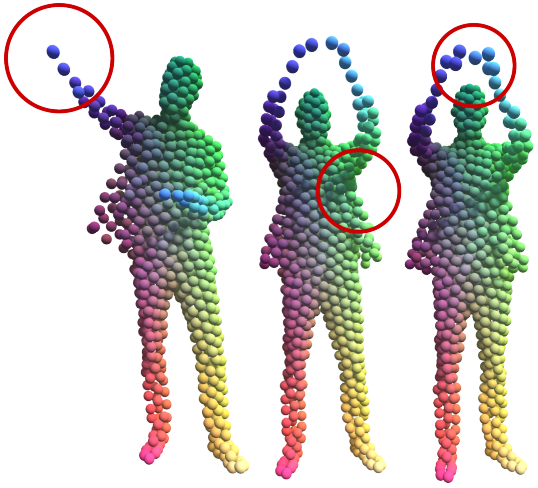
Forward and backward rigid predictions



## Animation Editing

- allows **propagation of changes over time** while preserving variable connectivity
- allows consideration of time-global information

Hácha, F., Dvořák, J., Káčereková, Z., & Váša, L. (2024). Editing mesh sequences with varying connectivity. Computers & Graphics, 121, 103943.

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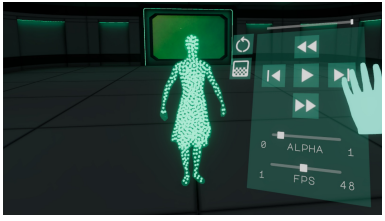
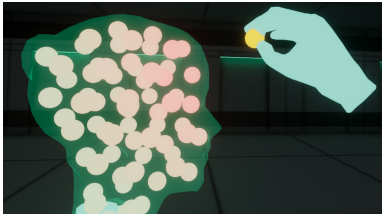
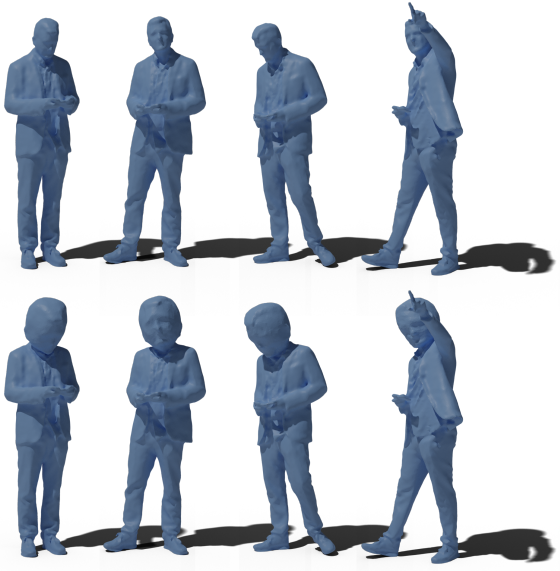


# Editing Triangle Mesh Sequences





# Compression of TVMs



Procedure

1. track volume centers
2. compute canonical position of centers
   - Multidimensional scaling on maximal distances
3. map each surface into canonical space via mesh editing $=>$ canonical shape
4. map canonical shape to each frame
   - only center positions are required

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**Advantages**

- beats per-frame approaches in RD-sense
  - tricky distortion evaluation because of change in connectivity
- invisible surface added in self-contact regions (within GoF)

# Thank you for your attention!

https://gitlab.kiv.zcu.cz/jdvorak/arap-volume-tracking

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