Occupancy Flow

4D Reconstruction by Learning Particle Dynamics

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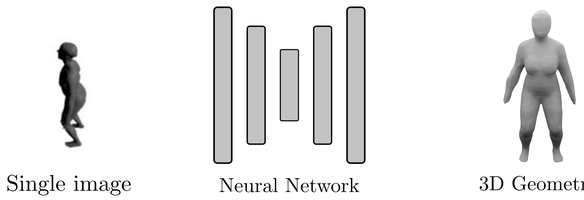
Motivation

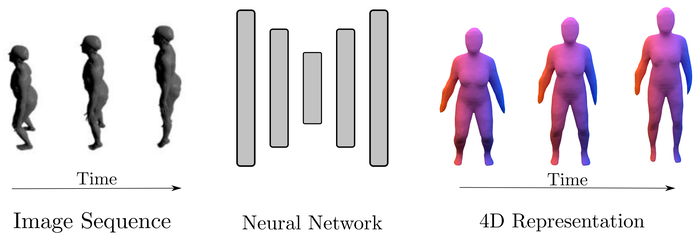
- Our world is full of **3D objects** in **motion**
- To act and reason autonomously, machines need an adequate **model of time-varying 3D geometry**
- Inferring such a model from **sparse sensory inputs** requires **knowledge of the world**
- Can we find a **4D representation** which can be **learned** from **obervations**?

Learning-based 3D Reconstruction

- Successful because **rich prior knowledge** can be used, e.g. to resolve ambiguities



- But in the real world, objects are **in motion**

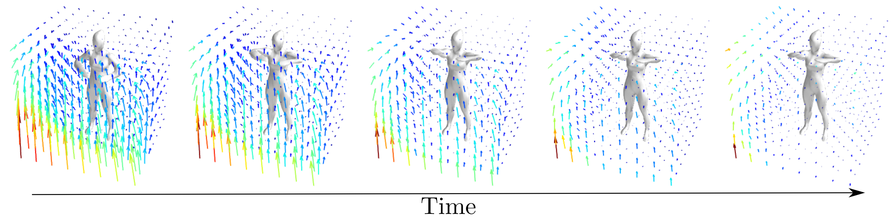


How can we extend the 3D models to 4D?

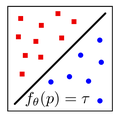
- Naïvely discretizing the temporal domain leads to
  - Sparsity in time
  - No correspondences
  - Slow inference

Our Representation

Represent **motion** by a temporally and spatially **continuous vector field** $v_\theta : \mathbb{R}^3 \times [0,T] \rightarrow \mathbb{R}^3$

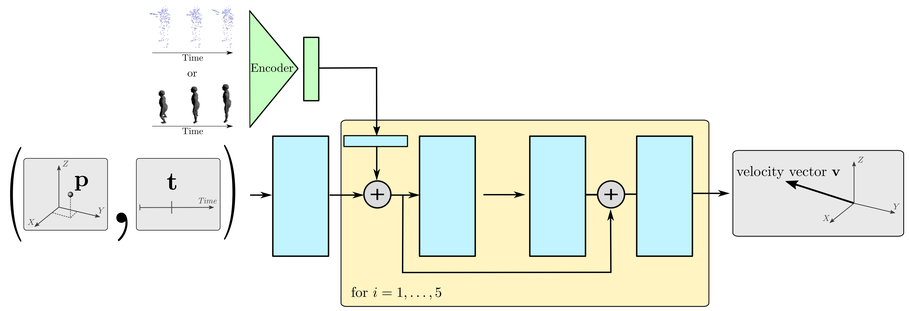


Represent **3D shape** at time 0 as the **continuous decision boundary** of a binary classifier $f_\theta : \mathbb{R}^3 \rightarrow [0,1]$

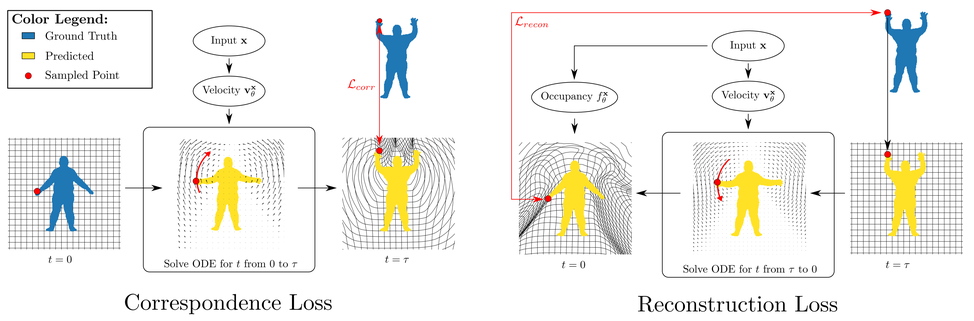


- \+ Spatially and temporally continuous
- \+ Implicit correspondences over time
- \+ Fast inference

Velocity Field Architecture

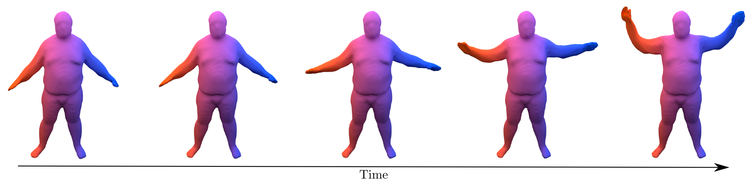


Loss Formulation



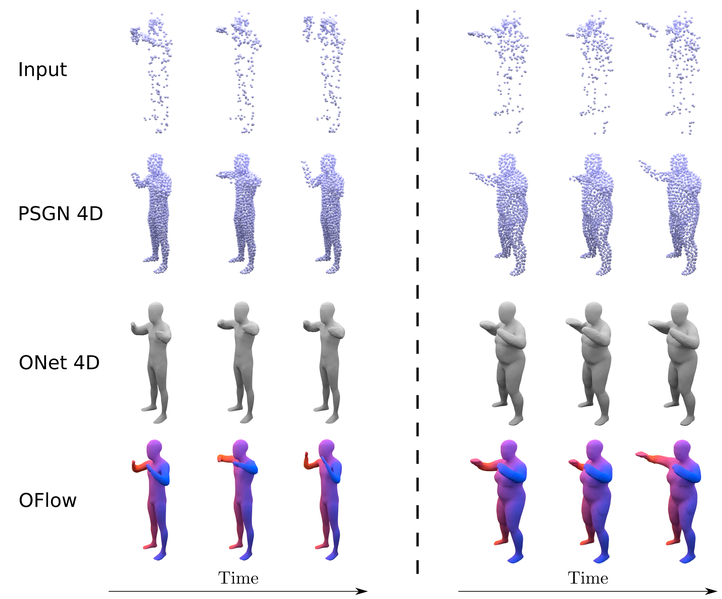
Experiments

Representation Power



	IoU	Chamfer	Time (s)
ONet 4D	**94.6 %**	**0.028**	15.845
OFlow	92.5 %	0.037	**0.689**

4D Point Cloud Completion



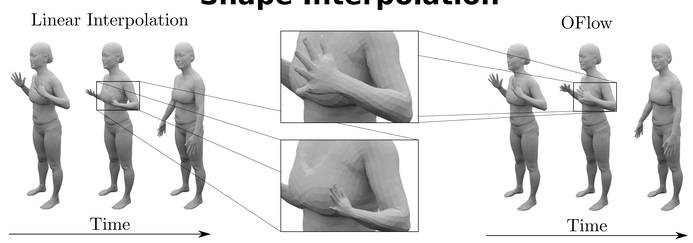
	IoU	Chamfer	Correspond.
PSGN 4D	-	0.258	2.576
PSGN 4D (w/ cor.)	-	0.265	2.580
ONet 4D	44.0 %	0.348	-
OFlow	56.6 %	0.193	0.292
OFlow (w/ cor.)	**59.6 %**	**0.166**	**0.226**

4D Reconstruction from Image Sequences (D-FAUST)

	IoU	Chamfer	Correspond.
PSGN 4D	-	0.108	3.234
PSGN 4D (w/ cor.)	-	0.101	0.102
ONet 4D	77.9 %	0.084	-
OFlow	79.1 %	0.077	0.129
OFlow (w/ cor.)	**81.2 %**	**0.096**	

4D Point Cloud Completion (D-FAUST)

Shape Interpolation



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