visuAAL

Privacy-Aware and Acceptable Video-Based Technologies and Services for Active and Assisted Living

ESR12. Measuring dementia behaviours through depth sensors

Joint visuAAL-GoodBrother conference

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Stockholm University

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Coláiste na Tríonóide, Baile Átha Cliath
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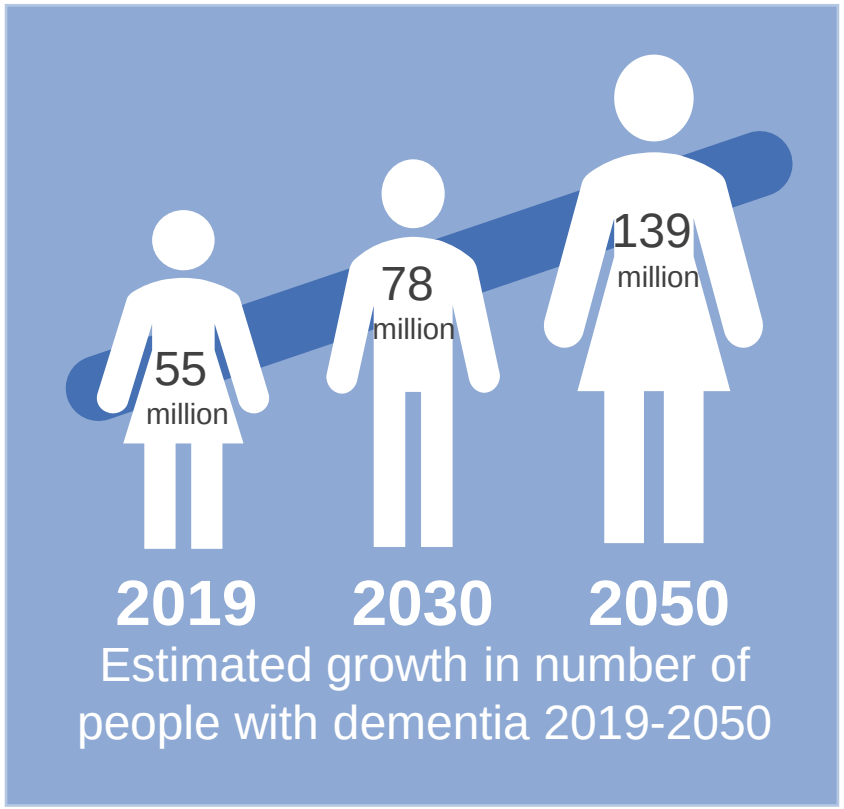
What's dementia?

- Syndrome in which there is a **deterioration in cognitive functioning beyond what might be expected from normal ageing** [1]
- One of the **major causes of dependency** among older people [2]

Why dementia?

- Behavioural changes **strongly correlated** with the degree of functional and cognitive impairment [2].
- **Behavioral and Psychological Symptoms of Dementia (BPSD):** agitation, aberrant motor behaviour, anxiety, irritability, depression, apathy, delusions, changes in sleep or appetite [3].



Data source: WHO [1]

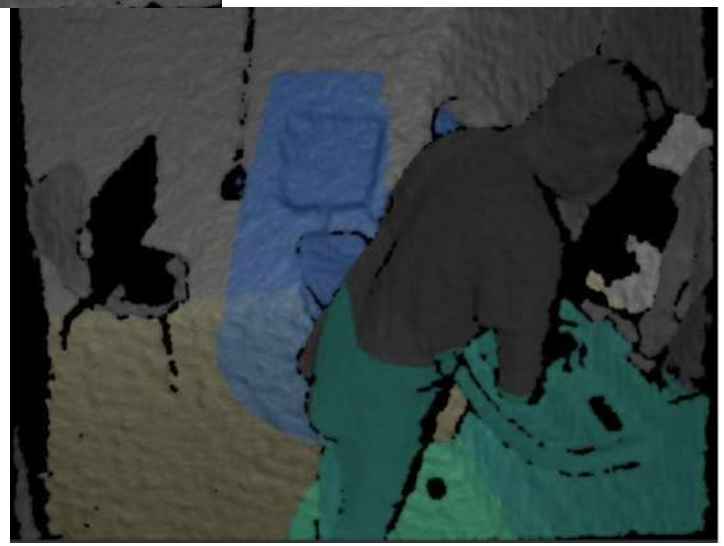
[1] World Health Organization https://www.who.int/news-room/fact-sheets/detail/dementia (accessed April 28, 2024)
[2] **Global status report on the public health response to dementia**. World Health Organization (2021)
[3] Joaquim Cerejeira, Luısa Lagarto, and Elizabeta Blagoja Mukaetova-Ladinska. "Behavioral and psychological symptoms of dementia". In: *Frontiers in neurology 3 (2012*), p. 73.

Data modality: depth

One of the main concerns: PRIVACY

RGB

Depth



AI for behaviour analysis from unobtrusive sensor data

Goal: Development of AI methods for **measuring** the **behaviours** of care home residents with **dementia** using **unobtrusive sensors (depth maps)**

In order to:

1. **Unobtrusive Remote Patient Monitoring**
2. **Provide assistance with ADLs**

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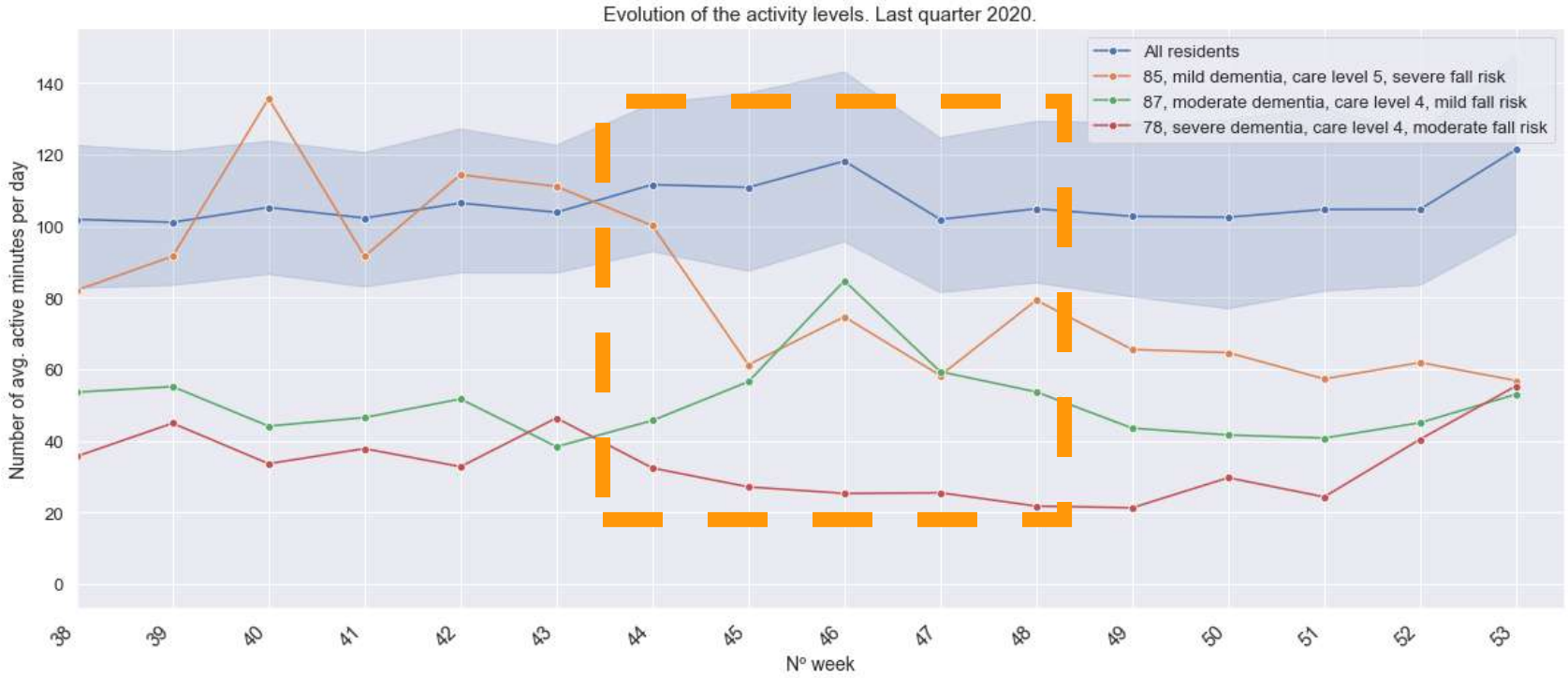
Ultimate goal

Detect and measure functional and behavioural changes indicative of dementia



Research Questions

RQ1. Different inputs for behaviour measurement

RQ2. Robust performance for real-world HAR

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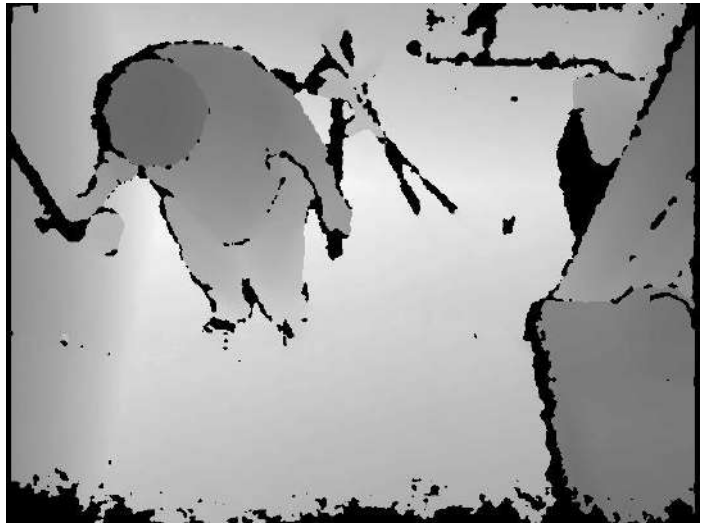
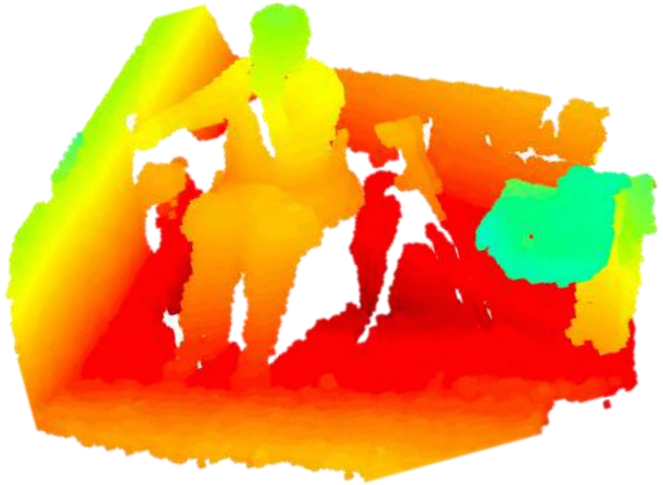
Different inputs

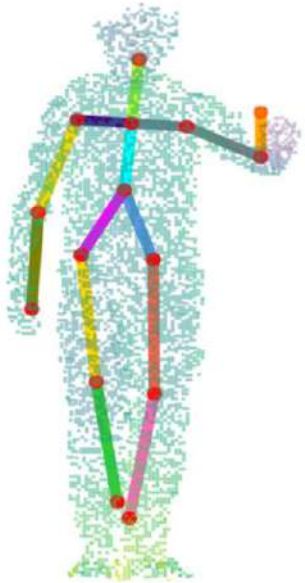
(Raw) depth images



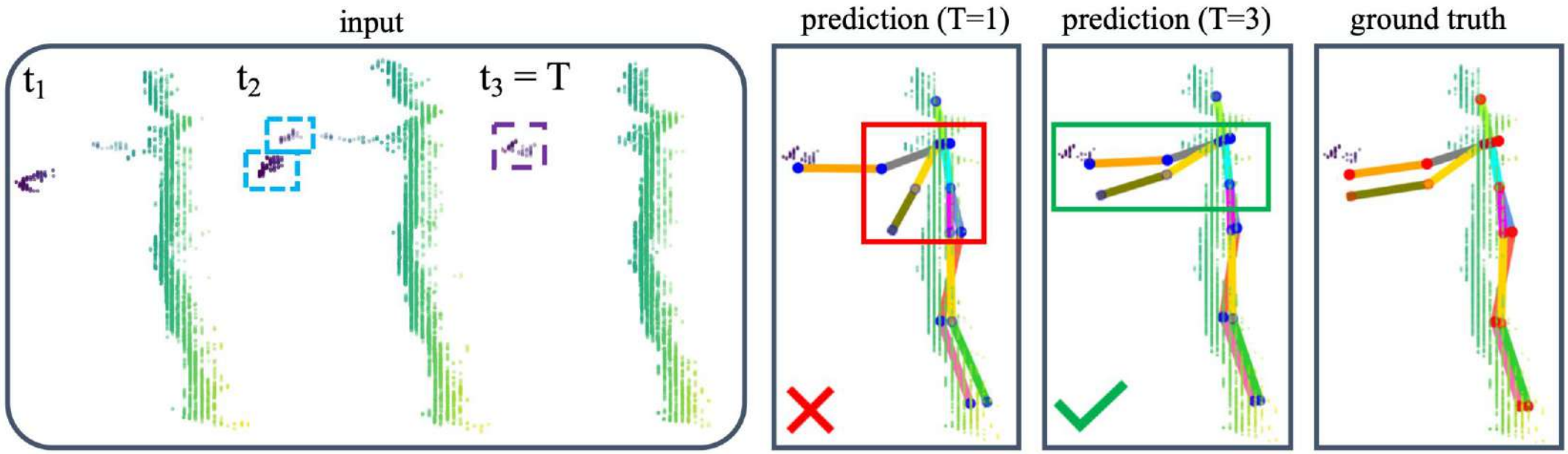
Point clouds from depth



Skeletons from depth/point clouds

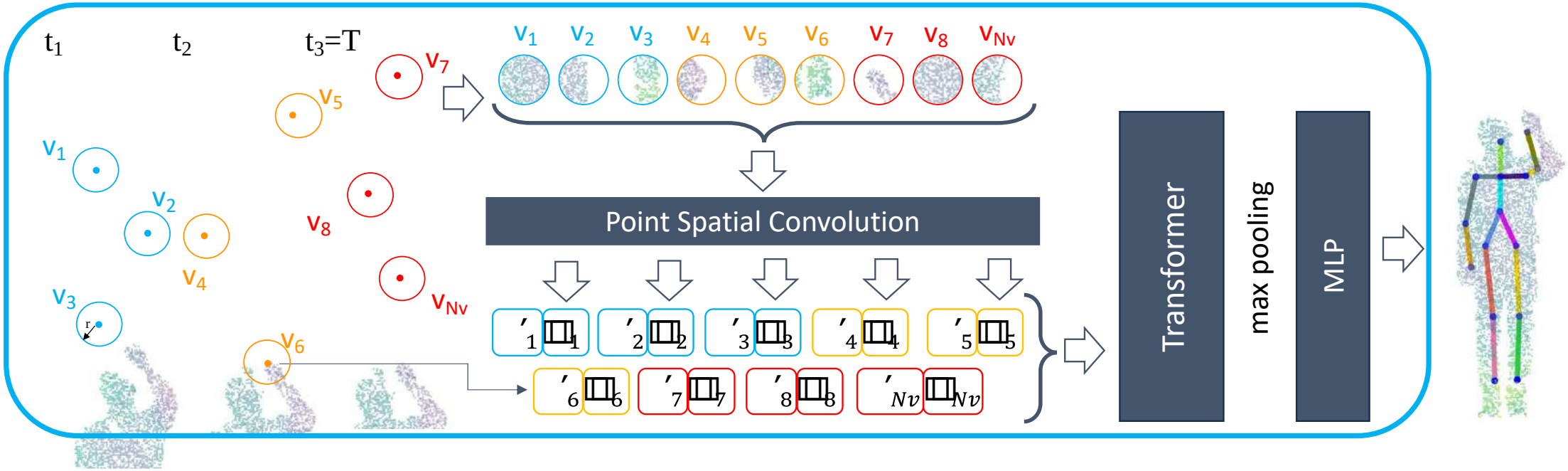


Motivation: Sequence information helps with occlusions and noise



SPiKE: Method

- How to process sequences of point clouds?
  - Spatial point convolution in local areas
  - Transformer + MLP for prediction of 3D joints

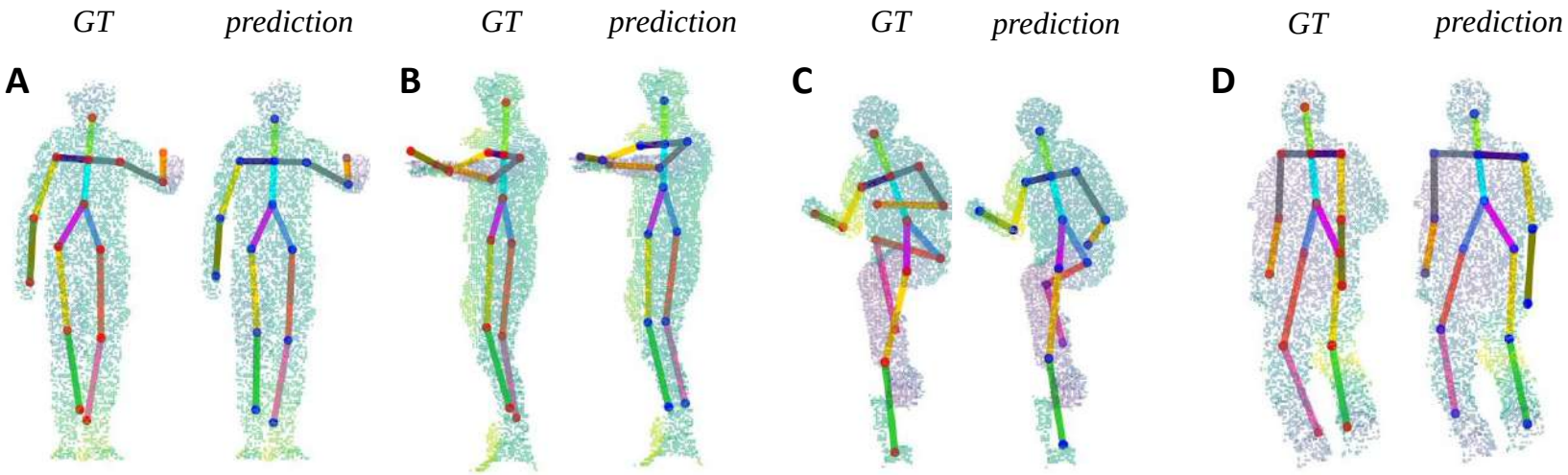


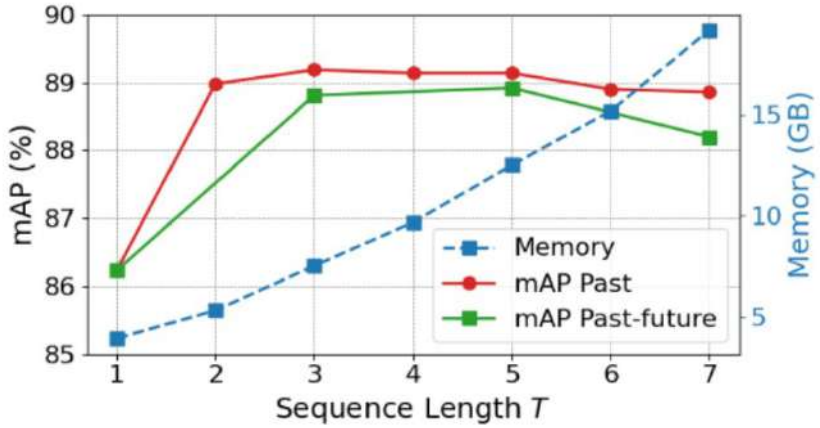
SPiKE: Comparison with SOTA

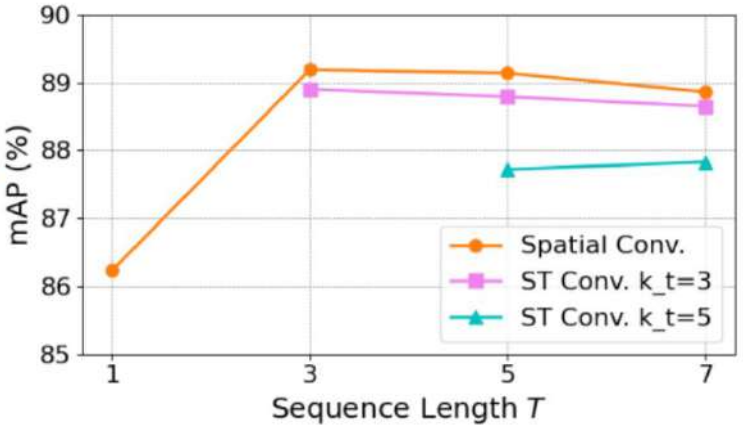
Table 1. Comparison with the state-of-the-art for ITOP front-view (0.1m mAP)

Method	Single Modality Methods						Multimodal Methods		
	V2V	A2J	WSM*	Zhou et al.	DECA	SPiKE (Ours)	WSM	AdaPose	HRNet+ RefiNet
	2018	2019	2020	2020	2021	-	2020	2021	2023
Modality	voxels	depth	points	points	depth	points	depth+points		
Head	98.29	98.54	-	96.73	93.87	98.42	98.15	98.42	-
Neck	99.07	99.20	-	98.05	97.90	99.47	99.47	98.67	-
Shoulders	97.18	96.23	-	94.38	95.22	97.48	94.69	95.39	-
Elbows	80.42	78.92	-	73.67	84.53	81.64	82.80	90.74	-
Hands	67.26	68.35	-	54.95	56.49	71.71	69.10	82.15	-
Torso	98.73	98.52	-	98.35	99.04	99.24	99.67	99.71	-
Hips	93.23	90.85	-	91.77	97.42	93.68	95.71	96.43	-
Knee	91.80	90.75	-	90.74	94.56	91.56	91.00	94.41	-
Feet	87.60	86.91	-	86.30	92.04	84.30	89.96	92.84	-
Upper B.	-	-	-	80.10	83.03	88.75	-	-	80.8
Lower B.	-	-	-	89.60	95.30	89.85	-	-	88.1
Mean	88.74	88.00	75.64*	85.11	88.75	**89.19**	89.59	**93.38**	84.2

SPiKE: Qualitative results and ablations



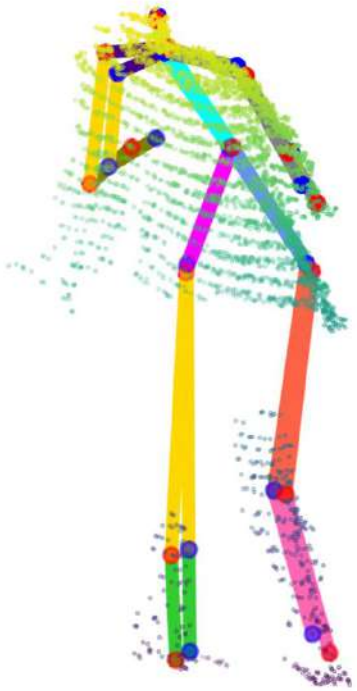




SPiKE: Conclusions and future steps

1. **Sequence information is useful**, but up to a certain sequence length
2. Spatial Convolutions help to preserve spatial structure (useful for HPE)
3. **SOTA in ITOP**

- Future work:
  How does SPiKE perform with **real-world data**?



Research Questions

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Domain gaps

vs

Benchmarks

Real-world data

2.5D
(self)-occlusions
complex, natural activities
unbalanced classes
frontal vs. tilted angles
sparsity and noise

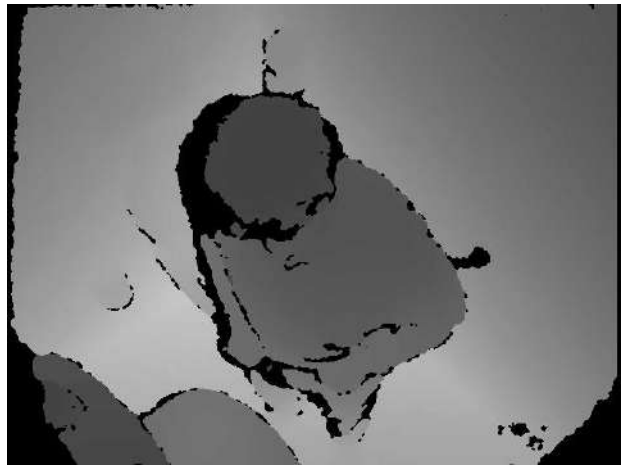
Bathroom Activities Dataset (BAD)

Description

- 50 full sequences
- **19 subjects with dementia** using the toilet
- 8 classes: walking around, undressing, sitting down, sitting on the toilet, standing up, dressing, washing hands
- 2 different locations:
  - **BAD1**: 3 subjects (36k frames)
  - **BAD2:** 16 subjects (21k frames)
- **Unbalanced** dataset:
  E.g.: in BAD2: sitting: 8k frames vs. sitting down: 679 frames

BAD1 – 3 subjects

BAD2 – 16 subjects



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Domain Gaps

Performance gap between benchmarks and real-world datasets

Performance gap between real-world scenes

Human Activity Recognition				
P4T [2]	Tested on (acc.)			
Trained on	*MSRAction3D*	*NTU 60 (cs)*	*BAD1 (cs)*	*BAD2 (cs)*
MSRAction3D	90.94	-	-	-
NTU 60 (cs)	-	90.2	-	-
BAD1 (cs)	-	-	53.15	7.23
BAD2 (cs)	-	-	7.90	63.63

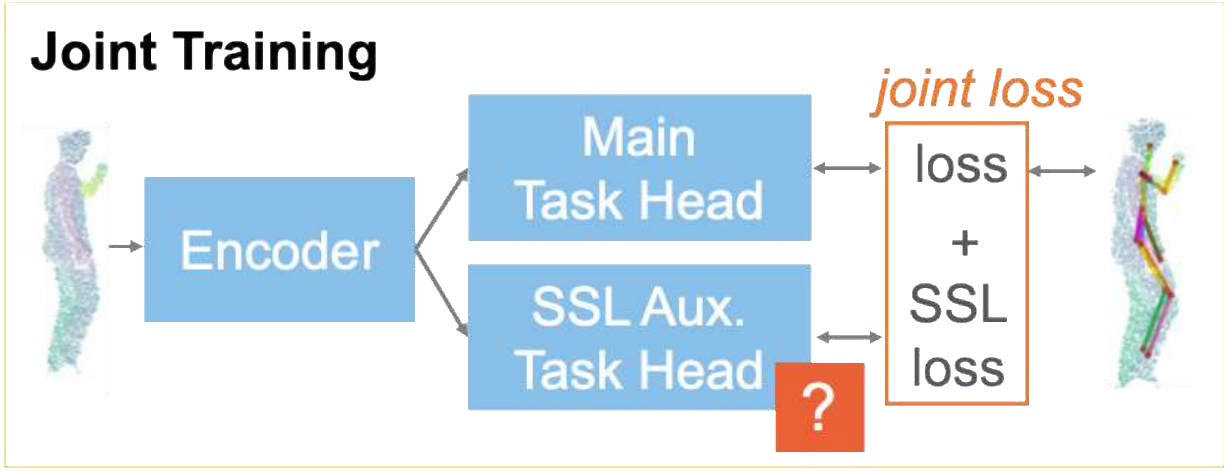
Human Pose Estimation		
SPiKE	Tested on (mAP@0.1m)	
Trained on	*ITOP-SIDE*	*ITOP-TOP*
ITOP-SIDE	89.19	24.75*
ITOP-TOP	36.81*	81.58*

Performance gap between views

**Work-in-progress*

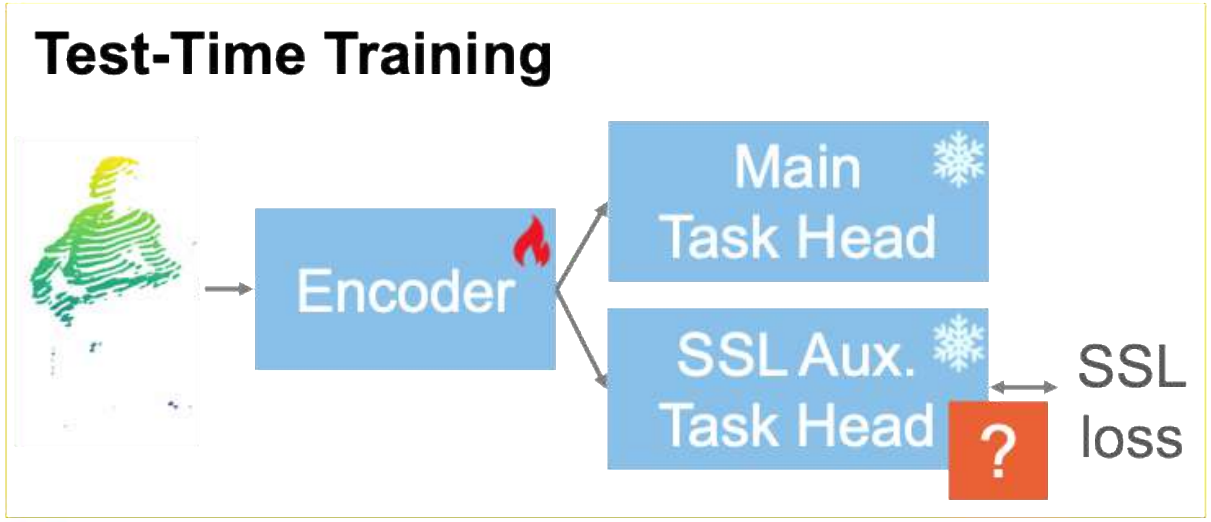
[2] Fan, H., Yang, Y., & Kankanhalli, M. (2021). Point 4d transformer networks for spatio-temporal modeling in point cloud videos. CVPR 2021

Test-Time Training for Domain Adaptation in Point Cloud Sequences

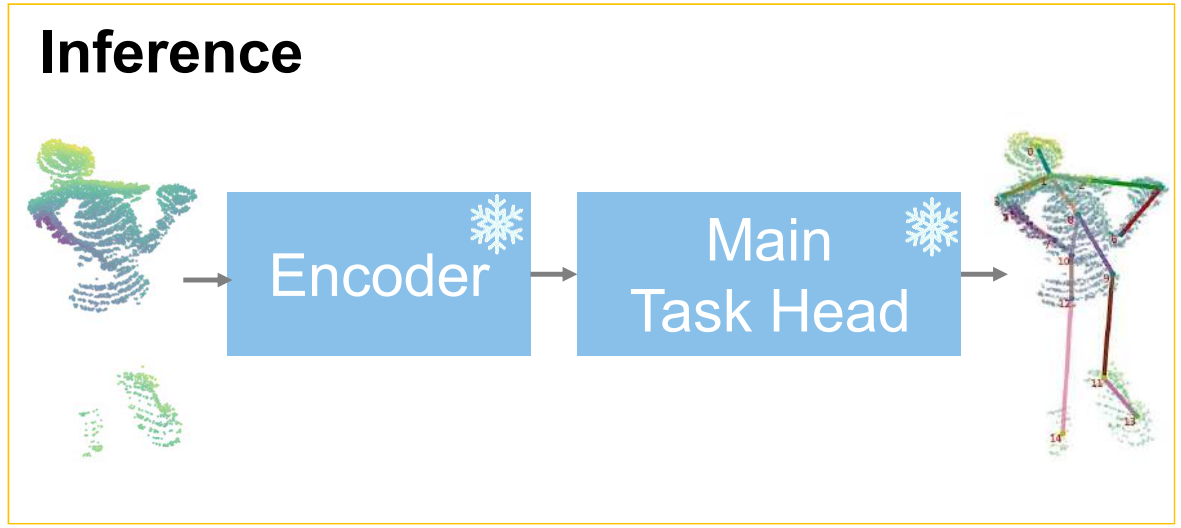


Source domain

Target domain



Target domain



Conclusions

- **Take away message**
  - Very promising achievements in benchmarks, how do they behave with real-world data?
  - **Need for evaluation in real-world scenarios and (potentially) domain adaptation for AAL applications**

- Future work:
  - Pre-training strategies
  - Self-supervised learning
  - Continual learning

Thank you!

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Measuring dementia behaviours through depth sensors

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Innovative Training Network on Privacy-Aware and Acceptable Video-Based Technologies and Services for Active and Assisted Living

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https://www.visuaal-itn.eu/

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