HMM-BASED APPROACHES TO MODEL MULTICHANNEL INFORMATION IN SIGN LANGUAGE INSPIRED FROM ARTICULATORY FEATURES-BASED SPEECH PROCESSING

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4 - University of Surrey, Guildford, UK

FNSNF
Swiss National Science Foundation
funded the project SMILE

idiap
INSTITUT DE RECHERCHE

EPFL

Sign language

Content of the video:

Human right - Freedom of language

Swiss french sign language

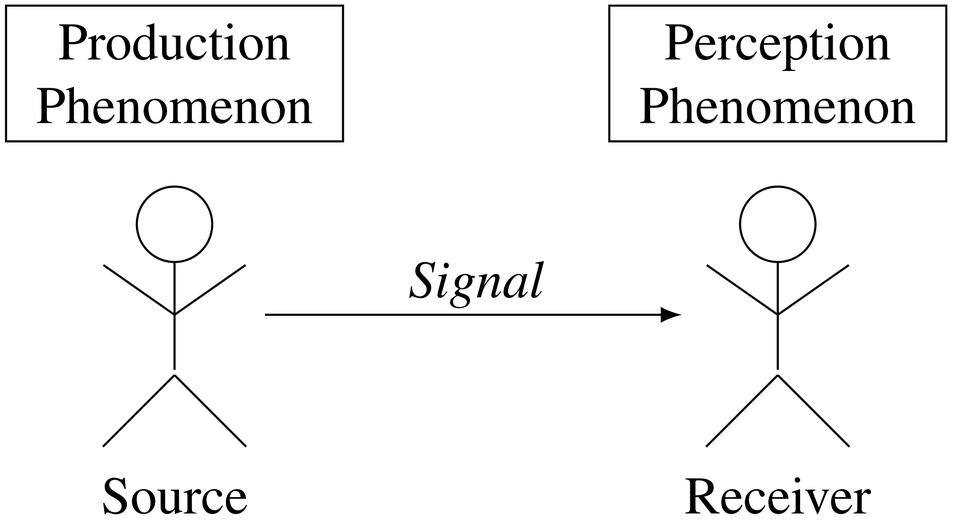
Multichannel information:

- Manual features - *hand shape, orientation, motion, position and location*
- Non-manual features - *facial expression, body posture, mouthings, mouth gestures*

Challenges:

1. How to reliably extract the multichannel information?
2. How to model the multichannel information?

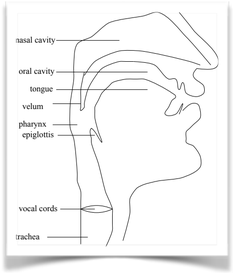
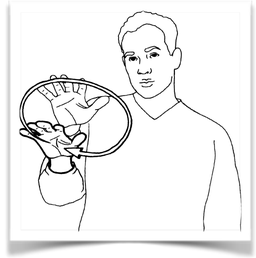
Communication process (1)



Necessitates:

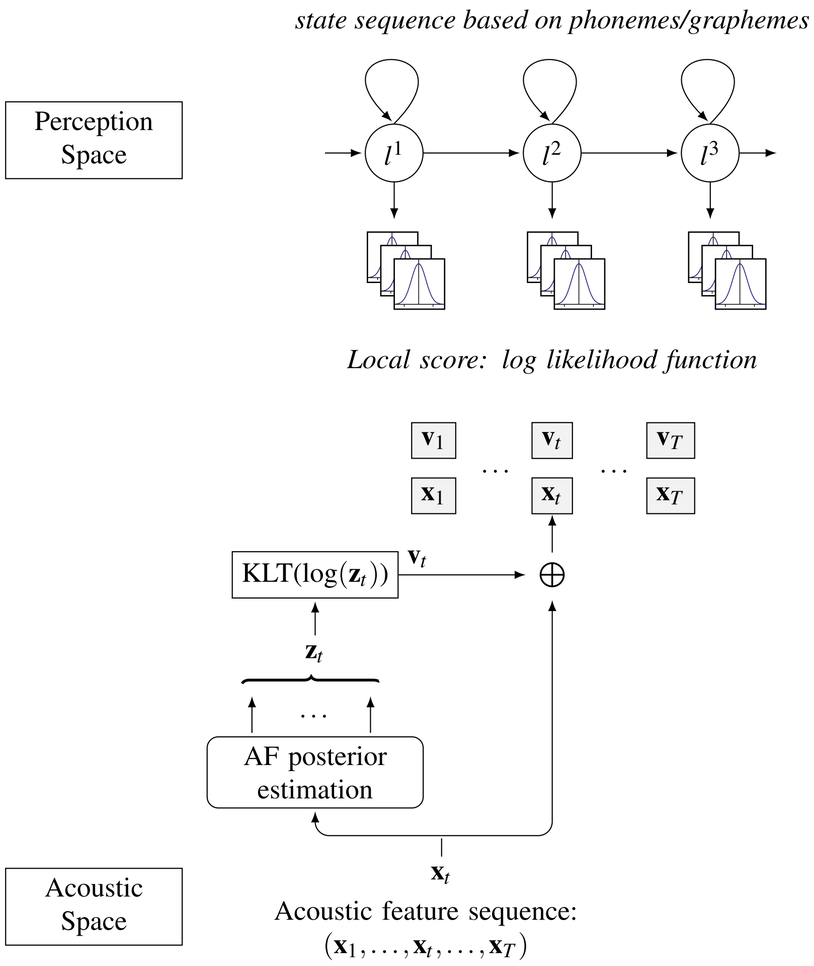
Modelling the synergy between the production phenomenon and the perception phenomenon in relation to the signal.

Communication process (2)

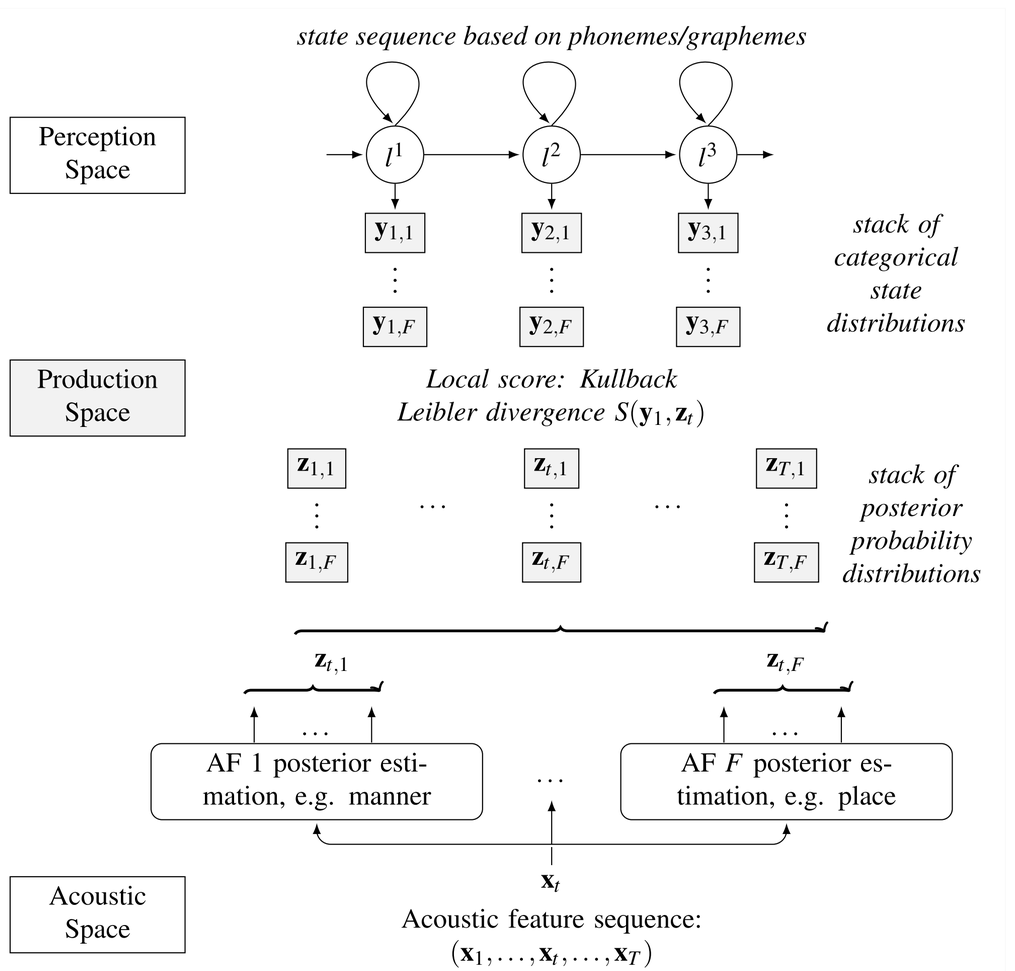
	Spoken Language			Sign Language		
	Production	→ Signal →	Perception	Production	→ Signal →	Perception
Communication process		→ Speech Signal →	Sequence of phonemes, words and sentences		→ Visual Signal →	Sequence of words and phrases
Production	Movement of tongue, lips and jaw, vocal fold vibration			Hand gestures, body posture, mouthing, facial expression, etc.		
Signal	**Audio** Sequential *(Cepstral feature seq.)* Parallel + Sequential *(Articulatory features)*			**Video** Parallel + Sequential		
Perception	Auditory *Seq. of phonemes, words and sentences*			Visual *Seq. of words and phrases*		

Inspiration from speech processing

Tandem approach



KL-HMM based approach



[14]* K. Livescu et al., « Articulatory feature-based methods for acoustic and audio-visual speech recognition: Summary from the 2006 JHU Summer Workshop », in Proc. of the ICASSP 2007

[15]* R. Rasipuram and M. Magimai.-Doss, « Articulatory feature based continuous speech recognition using probabilistic lexical modeling », Computer Speech and Language, vol. 36, 2016

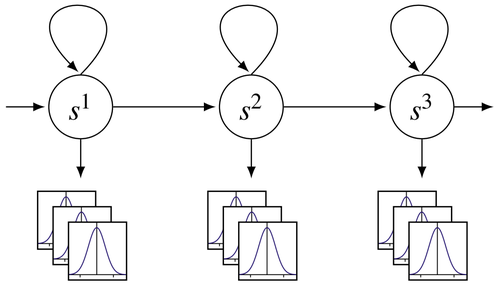
*Citation numbering comes from the paper

Proposed approaches

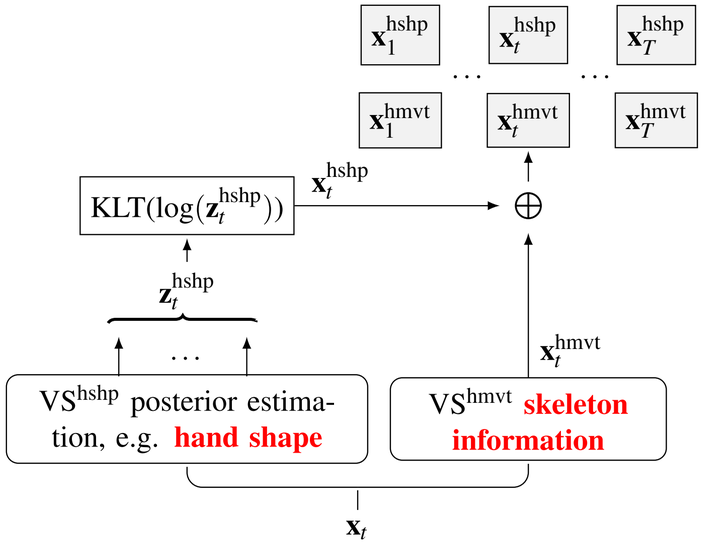
Tandem approach

How to define the state sequence?

Perception Space



Local score: log likelihood function



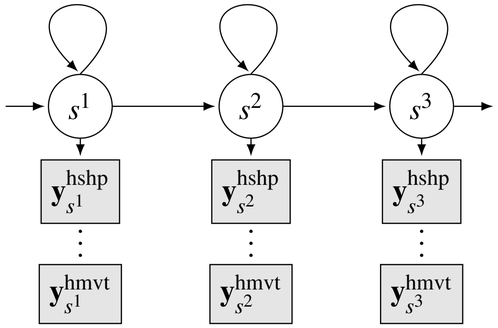
Visual Space

Visual feature sequence:
$(\mathbf{x}_1, \ldots, \mathbf{x}_t, \ldots, \mathbf{x}_T)$

KL-HMM based approach

How to define the state sequence?

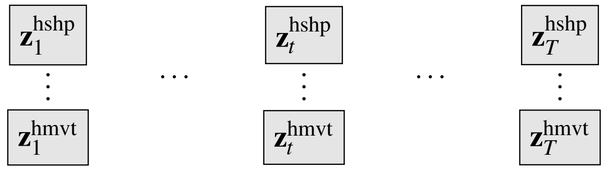
Perception Space



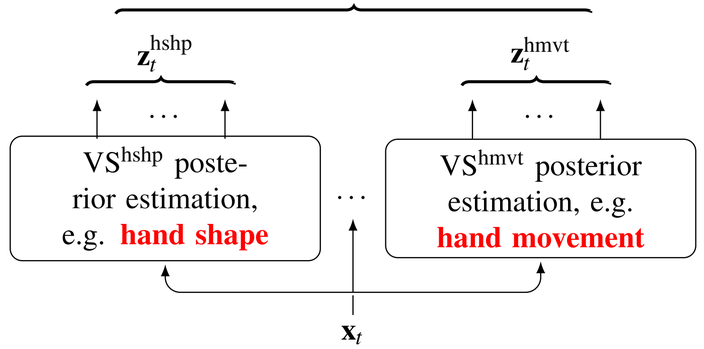
stack of categorical state distributions

Production Space

Local score: Kullback Leibler divergence $S(\mathbf{y}_{s^i}, \mathbf{z}_t)$



stack of posterior probability distributions



Visual Space

Visual feature sequence:
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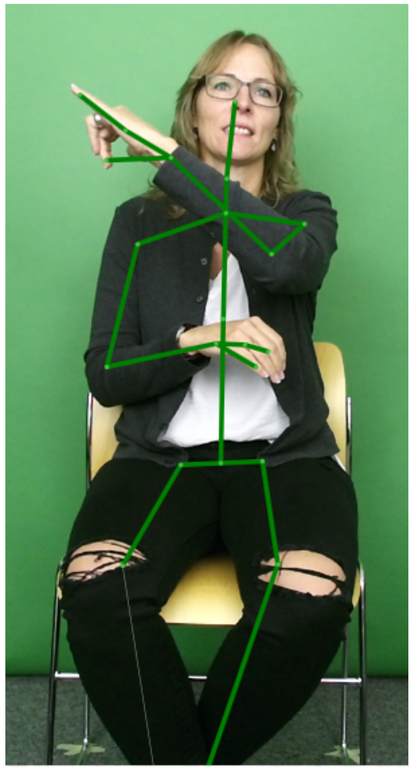
Dataset

SMILE Swiss German Sign Language Dataset

The SMILE dataset was created in the context of developing an assessment system for lexical signs of Swiss German sign language (DSGS)

- **100 isolated signs** of a DSGS vocabulary production test - **94 selected**;
- 11 adult L1 signers and 19 adult L2 signers = **30 signers** - (17 train, 3 dev, 10 test);
- SMILE dataset was collected with the **Microsoft Kinect v2 sensor** and the high speed and high resolution **GoPro video cameras**;
- Each sign was performed 3 times and only **the second pass was annotated -** Only the annotated «acceptable» signs of second pass was used in the following experiment;



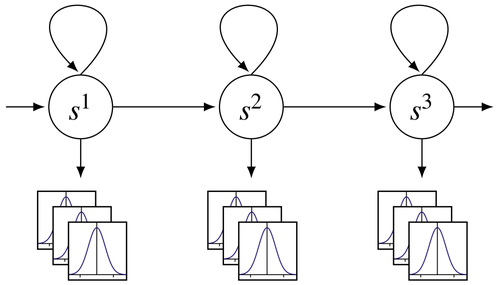
[22] S. Ebling et al., « SMILE Swiss German sign language dataset », in Proc. of the Language Resources and Evaluation Conference 2018

Proposed approaches

Tandem approach

How to define the state sequence?

Perception Space



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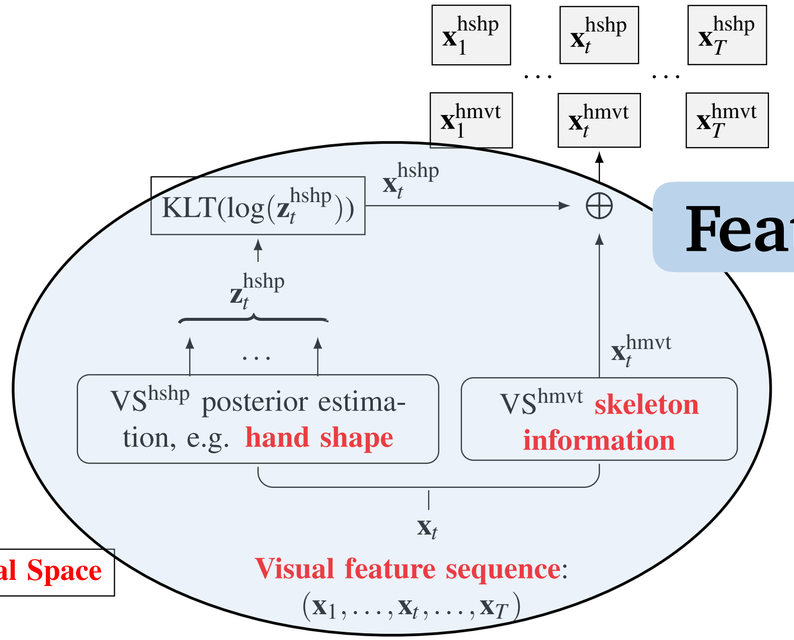
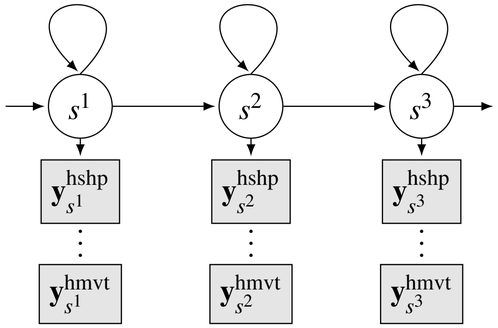


Visual Space

KL-HMM based approach

How to define the state sequence?

Perception Space



stack of categorical state distributions

Production Space

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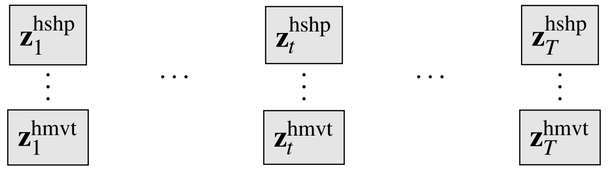
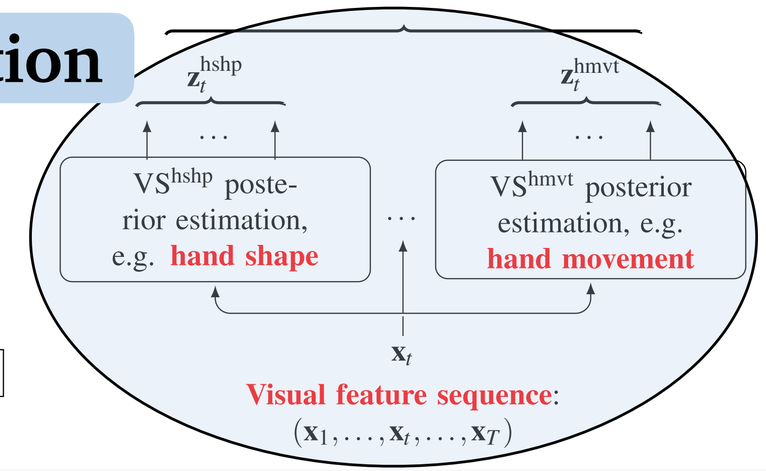


stack of posterior probability distributions

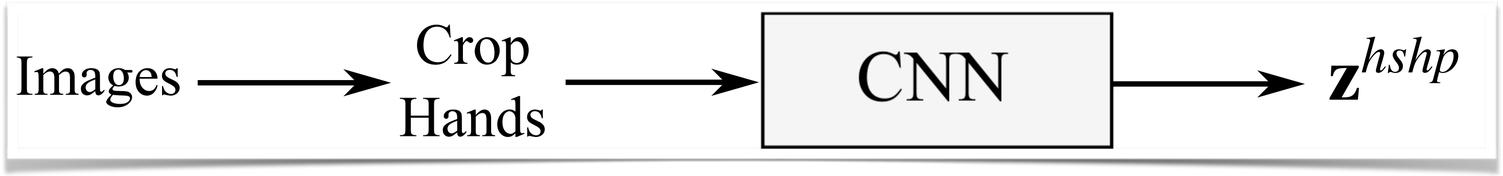


Visual Space

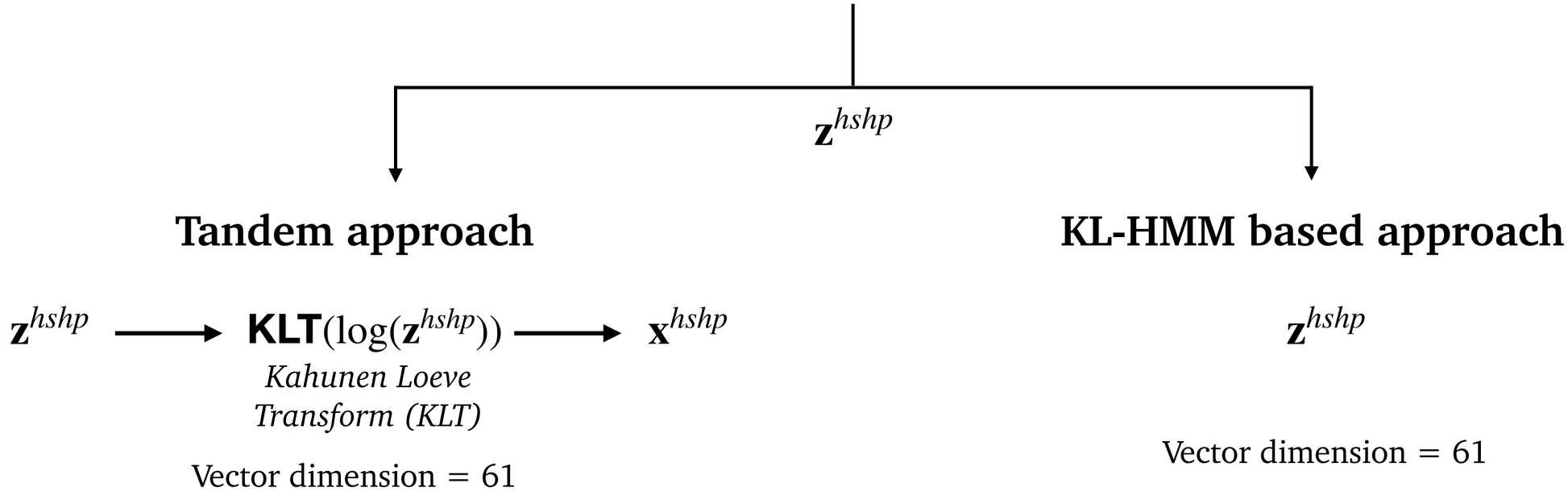
Feature Extraction

Feature extraction - Hand shape

We used the Deep hand net developed by [23] :

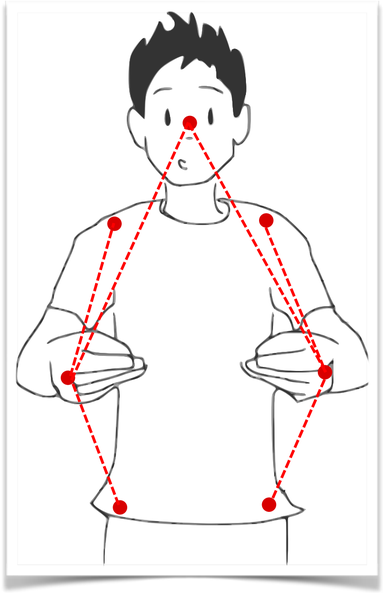


The CNN is trained on the **1-Million-Hands dataset [23]** containing 60 hand shapes + 1 transition shape.



[23] O. Koller, H. Ney, and R. Bowden, « Deep hand: How to train a CNN on 1 million hand images when your data is continuous and weakly labelled », in Proc. of the IEEE CVPR 2016

Feature extraction - Hand movement



+

- **Position features** given by 3D coordinate of a human skeleton:

$$\mathbf{p}_t^{\mathbf{C}} = \frac{\mathbf{hand} - \mathbf{C}}{|\mathbf{head} - \mathbf{neck}|/4}, \text{ where } \mathbf{C} \in \{\mathbf{head},\ \mathbf{shoulder},\ \mathbf{hip}\};$$

- **Velocity features** given by delta features: $\mathbf{v}_t^{\mathbf{C}} = \mathbf{p}_t^{\mathbf{C}} - \mathbf{p}_{t-2}^{\mathbf{C}}$.

=

Movement features are concatenation of position and velocity of both hands according to head, shoulder hip coordinate centers.

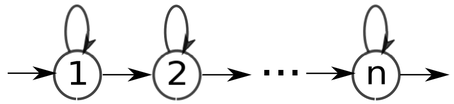
$\mathbf{x}^{hmvt}$

Tandem approach

$\mathbf{x}^{hmvt}$

Vector dimension = 36

KL-HMM based approach



$\mathbf{x}^{hmvt}$ → GMM → $\mathbf{z}^{hmvt}$

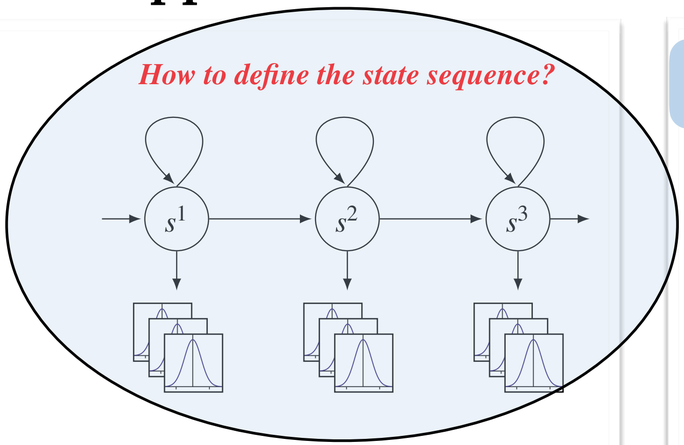
priors

Vector dimension = 849

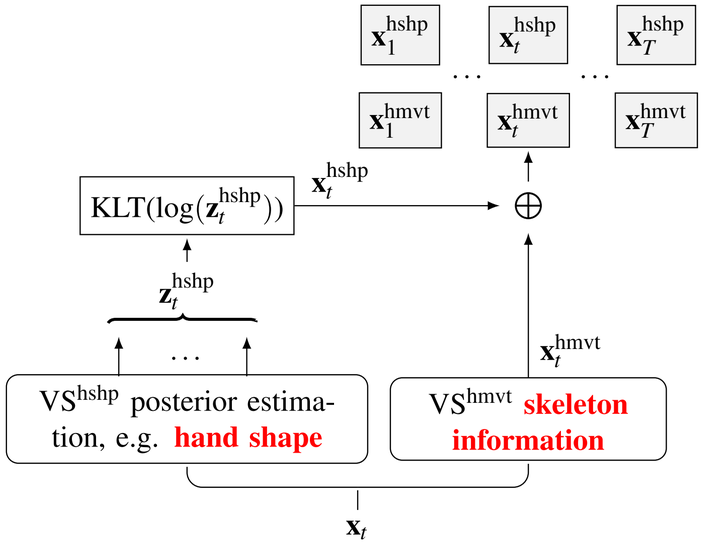
Proposed approaches

Tandem approach

Perception Space



Local score: log likelihood function



Visual Space

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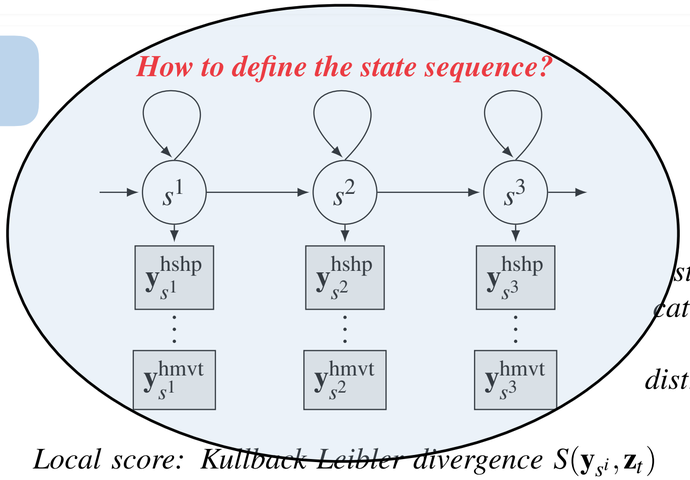
KL-HMM based approach

Model

Perception Space



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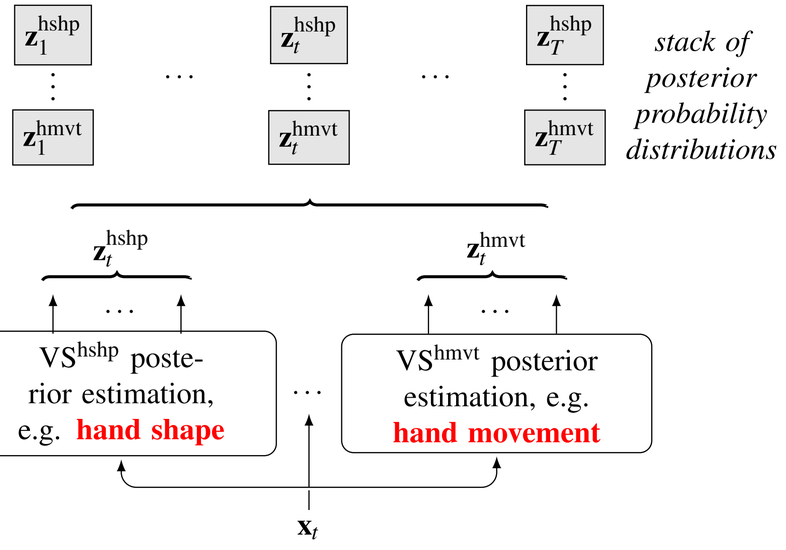

stack of posterior probability distributions

Visual Space

Visual feature sequence:
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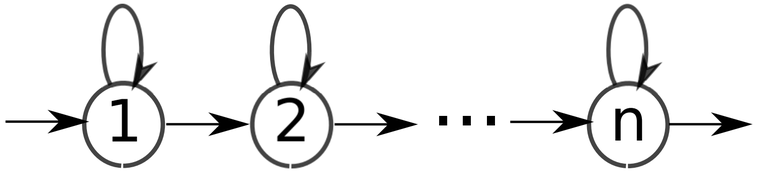
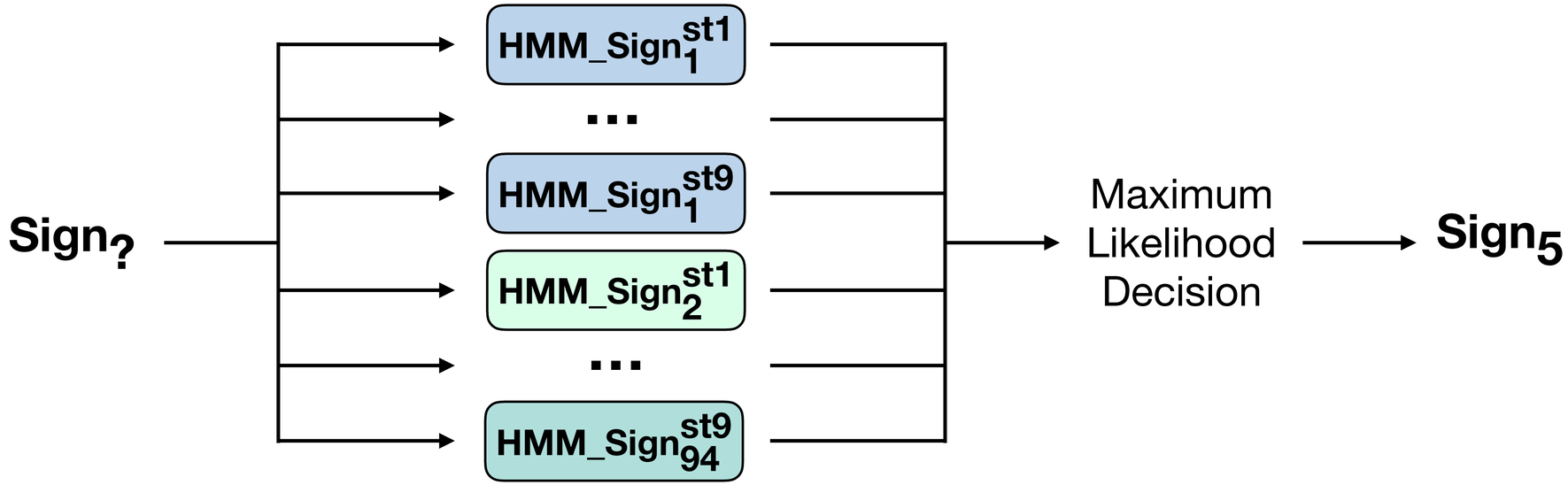
HMM-based recognition framework

- **Training:** Multiple left-to-right HMM-based systems are trained for each sign



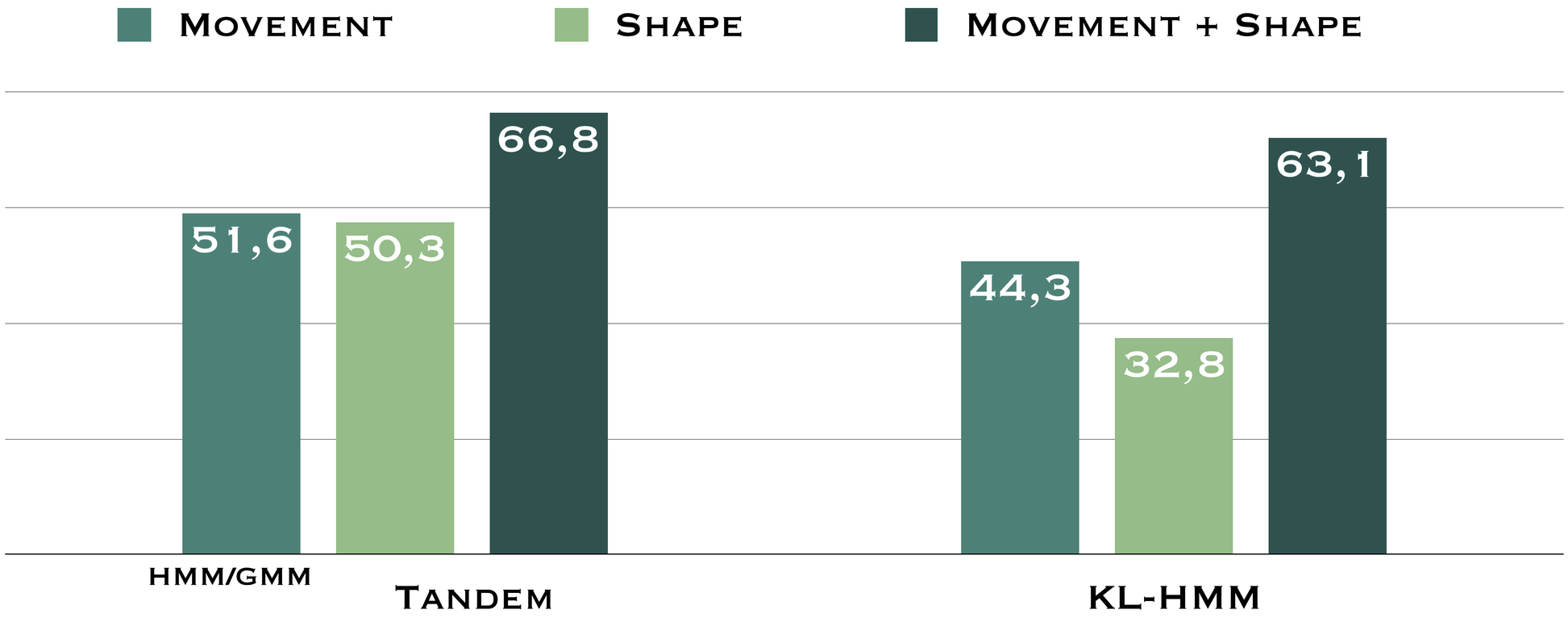
depending on the number of state n: where $3 \leq n \leq 9$

- **Recognition:** Model selection framework

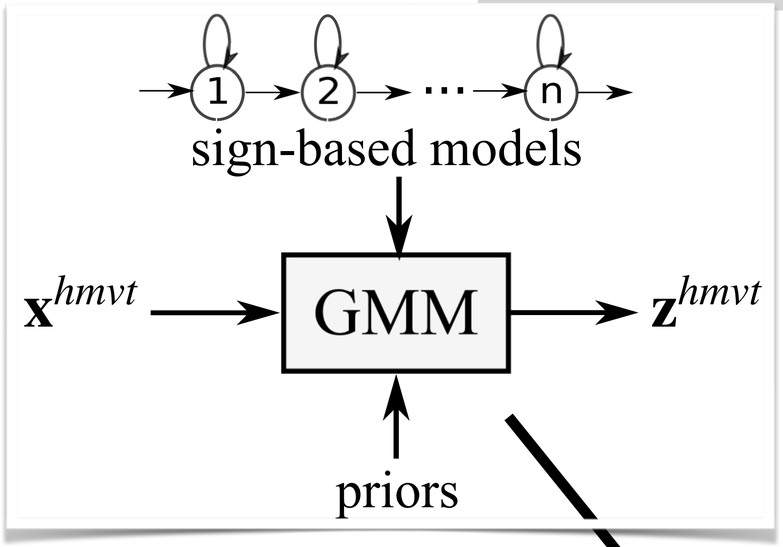


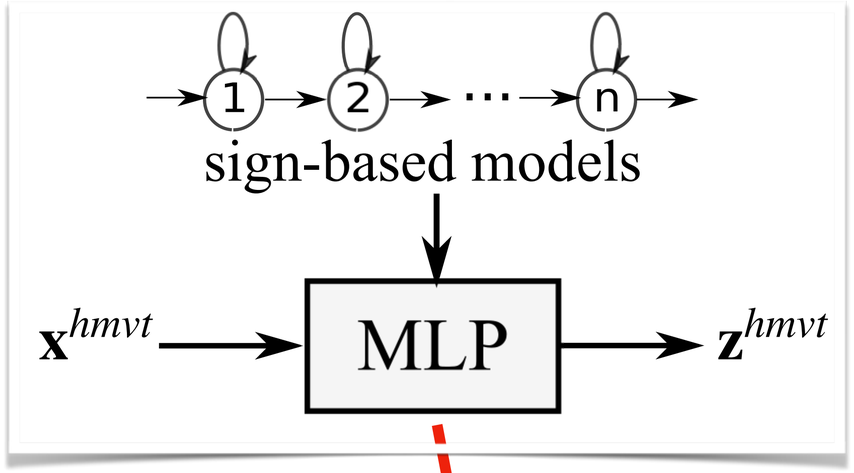
Sign language recognition results

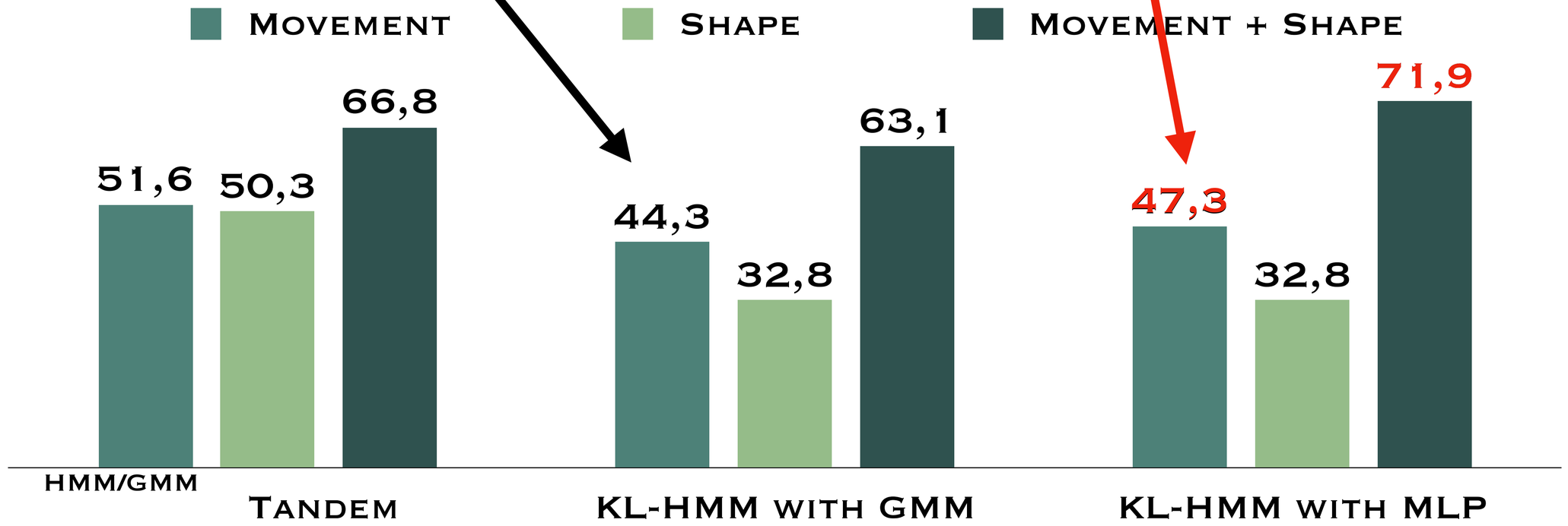
Sign recognition accuracy



Analysis - Hand movement feature





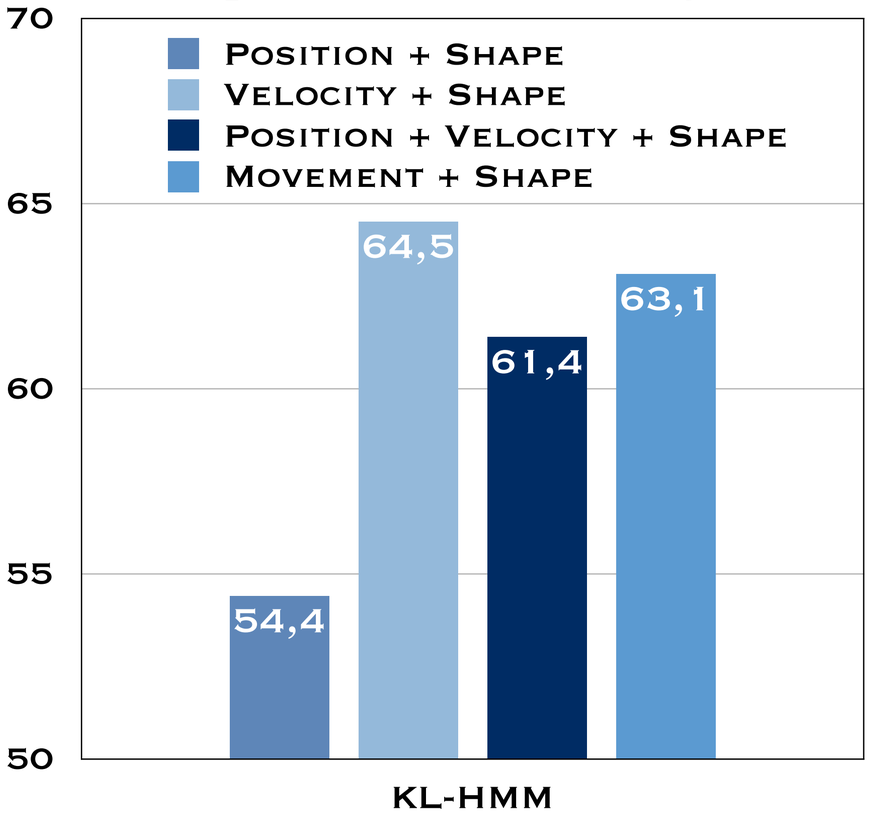


Further analysis

Advantages of KL-HMM approach

1

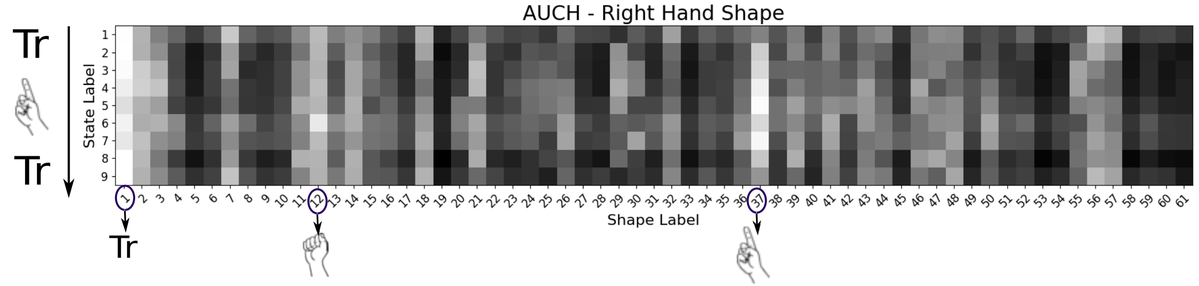
Possibility of separating the movement features into position and velocity



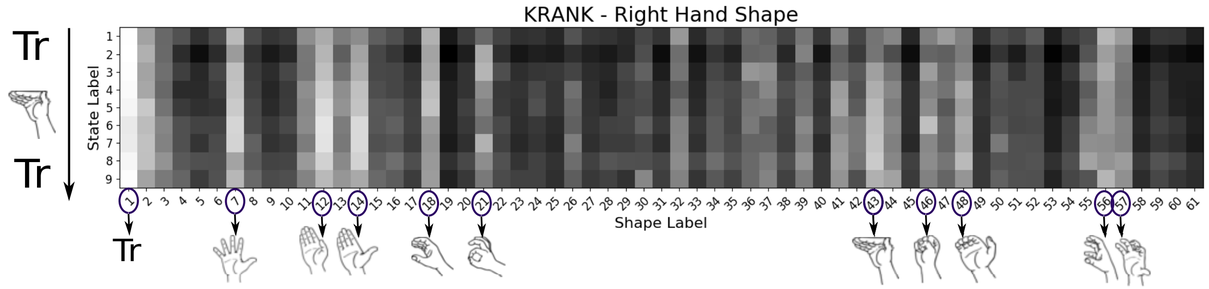
2

Possibility to analyse the trained categorical distributions ;
Here the hand shape ones

Well-recognised example



Poor-recognised example



Summary

- elucidated the link between articulatory feature-based speech processing and sign language processing
- proposed two HMM-based approaches to model multichannel information in sign language
  - Tandem approach and KL-HMM based approach
  - Both approaches yielded promising results
- demonstrated flexibility and interpretability of the KL-HMM approach

On-going Work ➡ developing an assessment system for Swiss German sign language learners (SMILE project).

A video of the assessment system demonstrator is available at:
www.idiap.ch/project/smile/news/smile-how-it-works

Questions ?

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