Snapture - a Hybrid Hand Gesture Recognition System

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KNOWLEDGE TECHNOLOGY

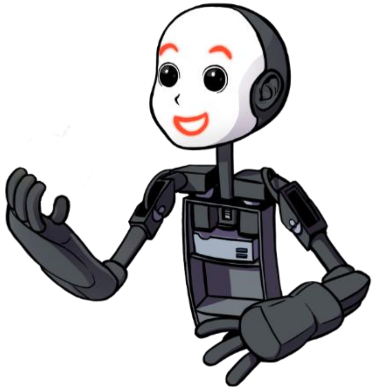
http://www.informatik.uni-hamburg.de/WTM/

Motivation

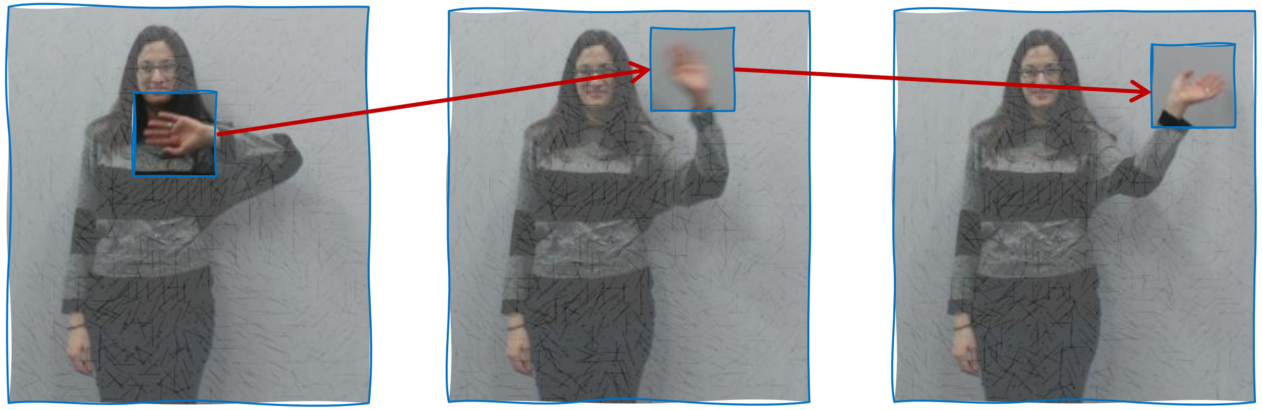
- Hand gesture applications
- Gesture taxonomy

Static

Dynamic



- Vision-based systems



Hello

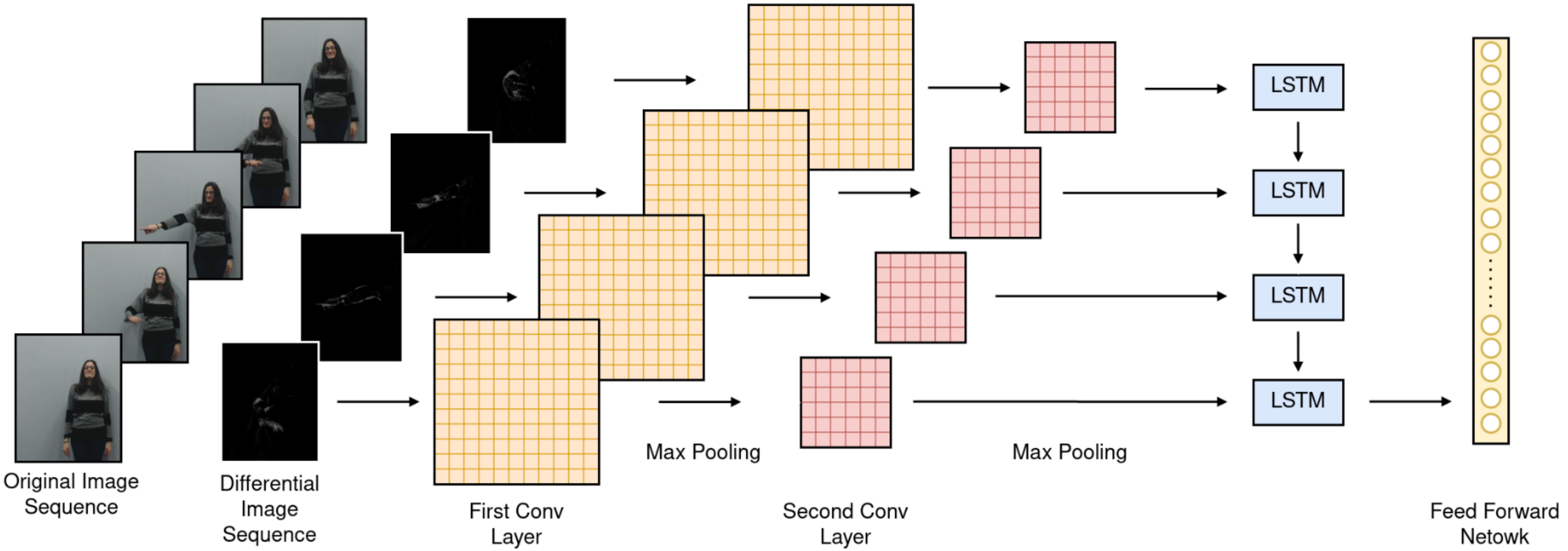
Hand detection

Hand tracking

Recognition

CNNLSTM

- Evaluated using the Tsironi GRIT dataset (available on WTM website)
- We reproduce the results.



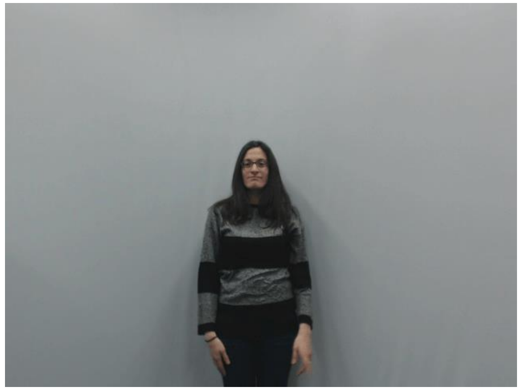
Research Questions

- CNNLSTM
  - How influenced is the CNNLSTM network by subject variability?
  - How efficient is the CNNLSTM network at learning co-speech gestures?

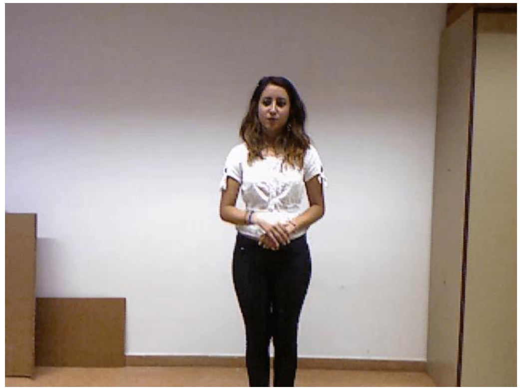
- Snapture
  - How to identify the peak of the gesture and extract the handshape using RGB data only?
  - How to regulate the integration of the hand details into a dynamic gesture recognition system?

1. How influenced is the CNNLSTM network by subject variability?

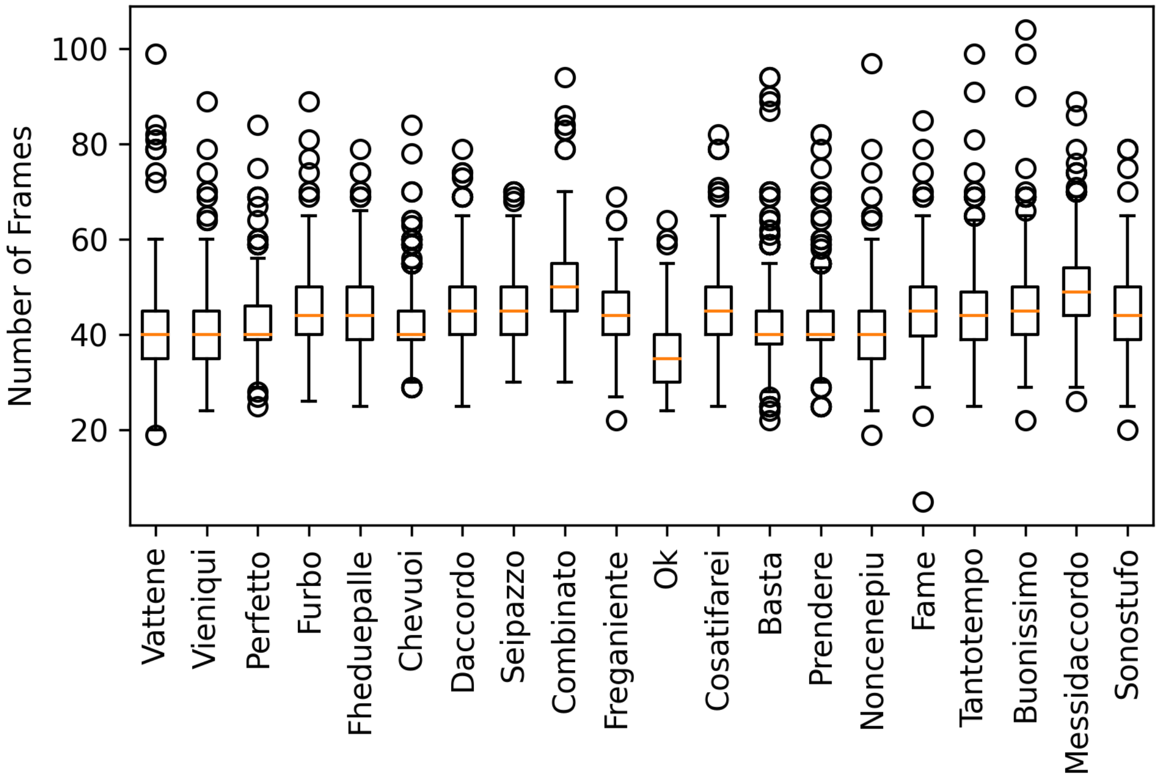


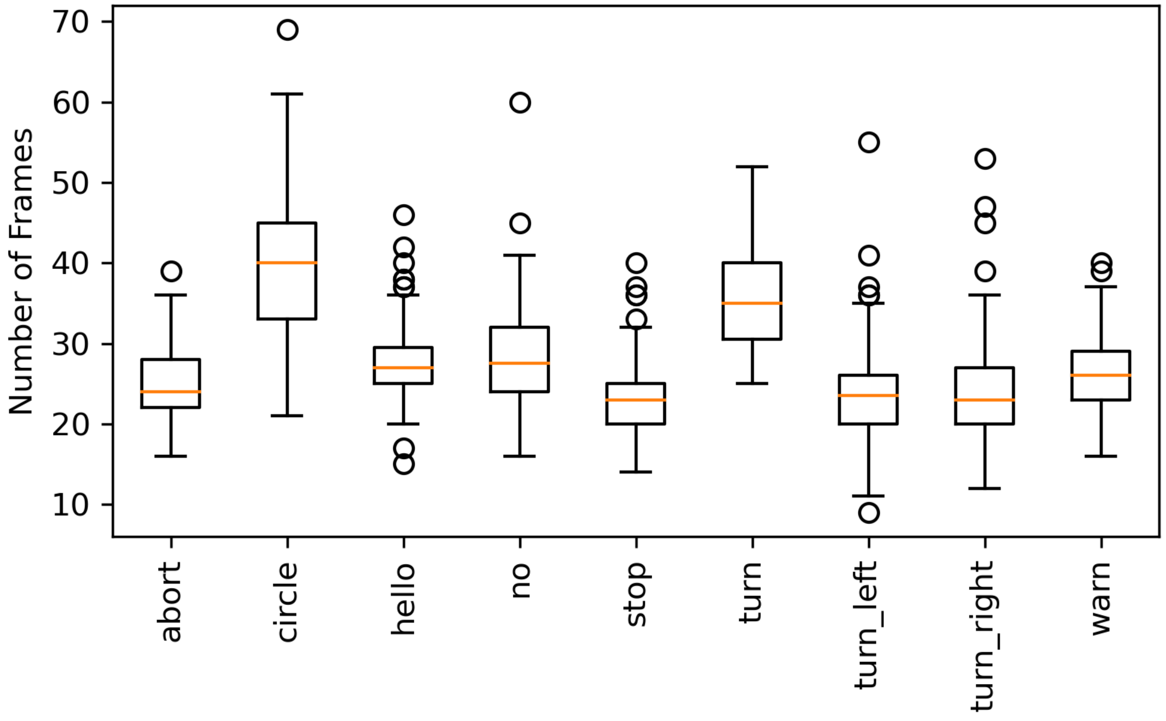
Prendere Daccordo Turn Left No

CNNLSTM – Subject Variability



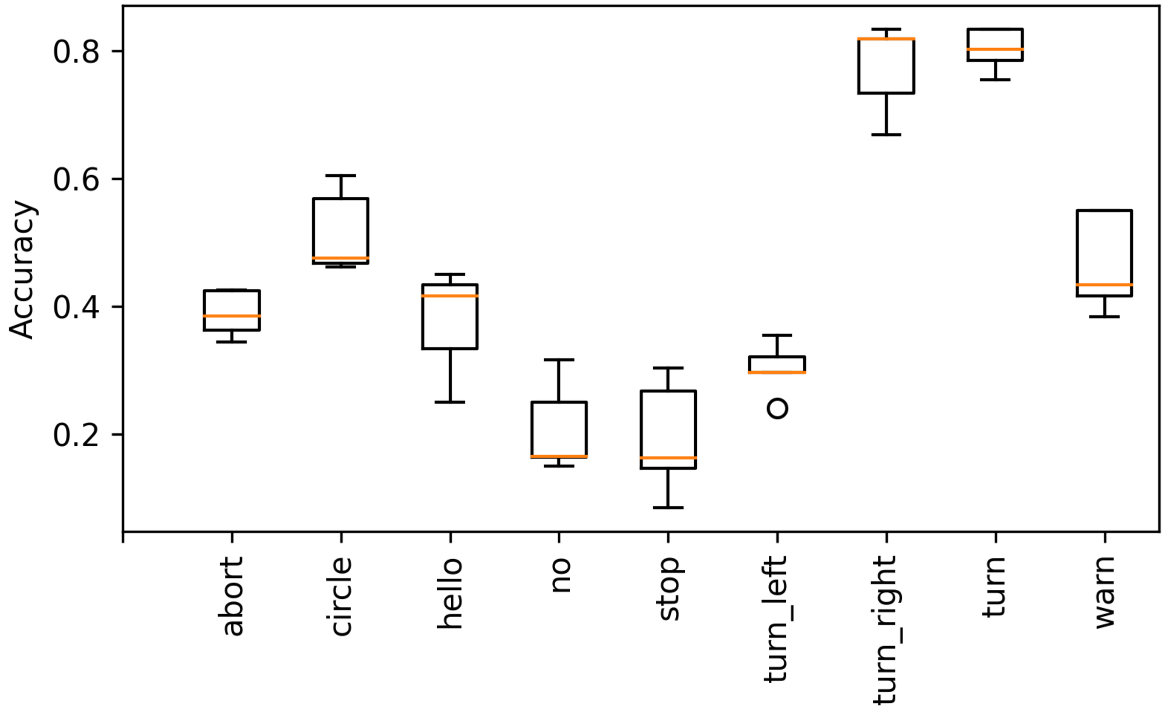
Montalbano (Chalearn Challenge)



Tsironi GRIT

CNNLSTM – Subject Variability

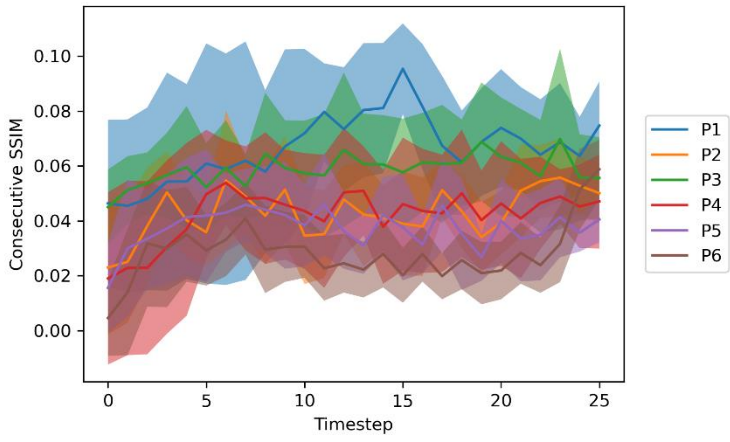
- Experiment using the GRIT dataset
- Evaluate on unseen subjects (Leave-one-out approach)
- Low accuracy for most classes



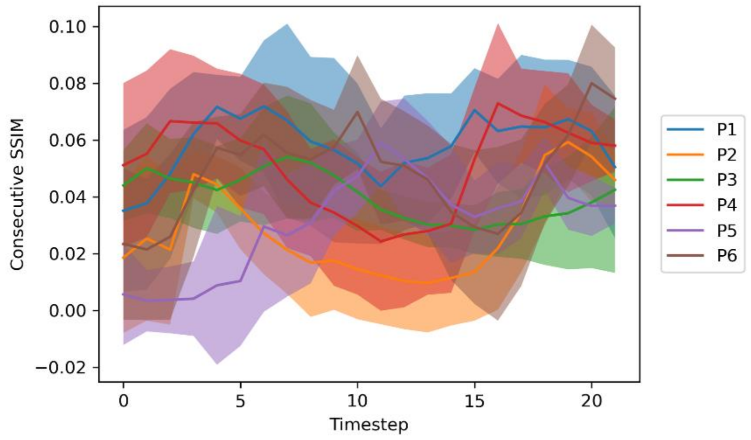
Accuracy per class, avg. over all subjects, avg. of 5 trials

CNNLSTM – Subject Variability

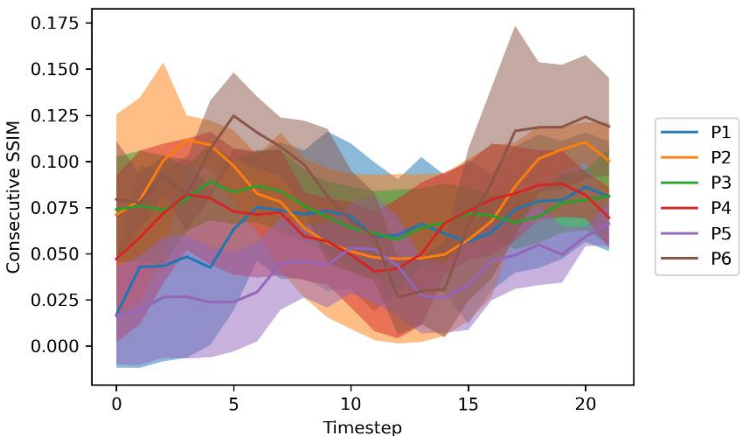
- Motion profile of the worst-case classes: *No*, *Stop*,
- and the best-case classes: *Turn Right*, *Turn*
- **Consequence**: train on data of all subjects.



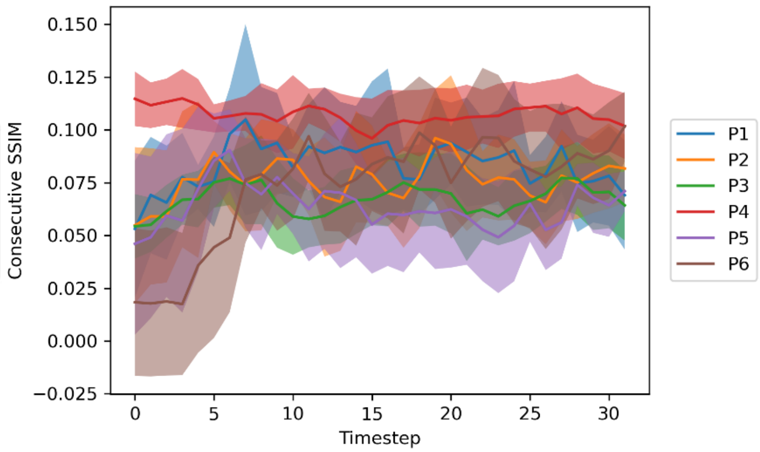
No



Stop



Turn Right



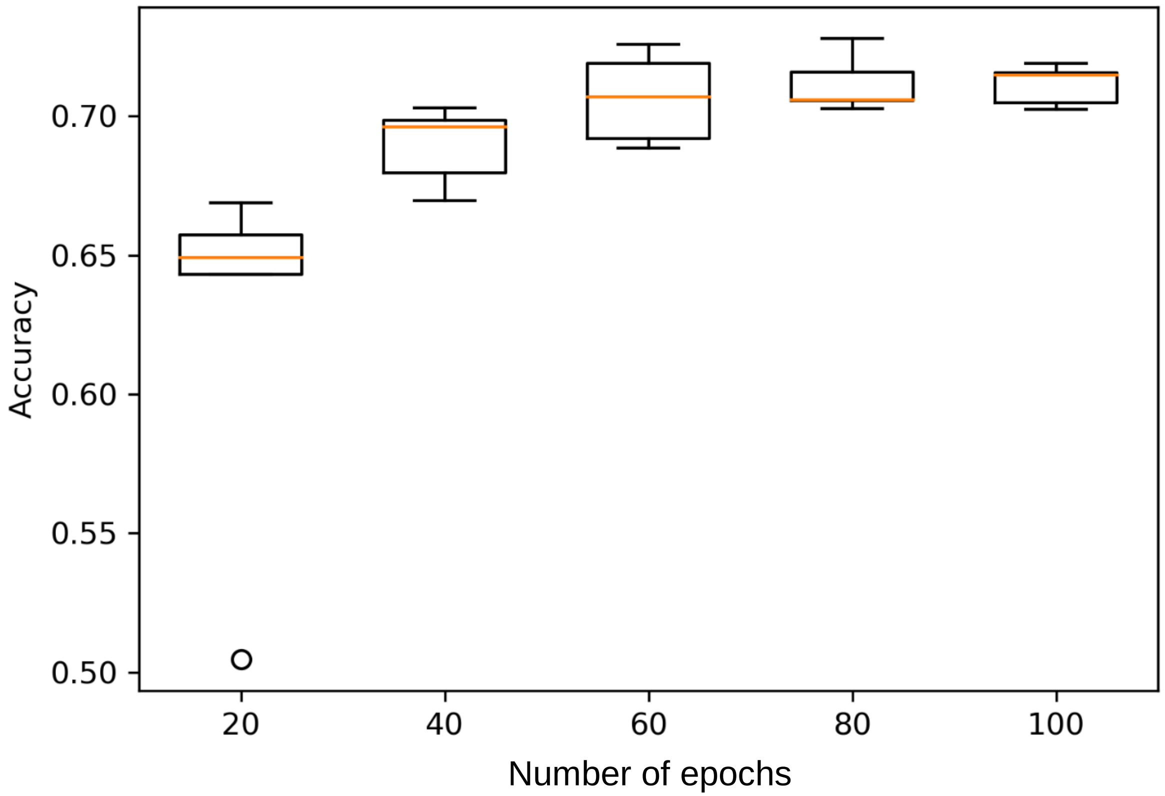
Turn

2. How efficient is the CNNLSTM network at learning co-speech gestures?

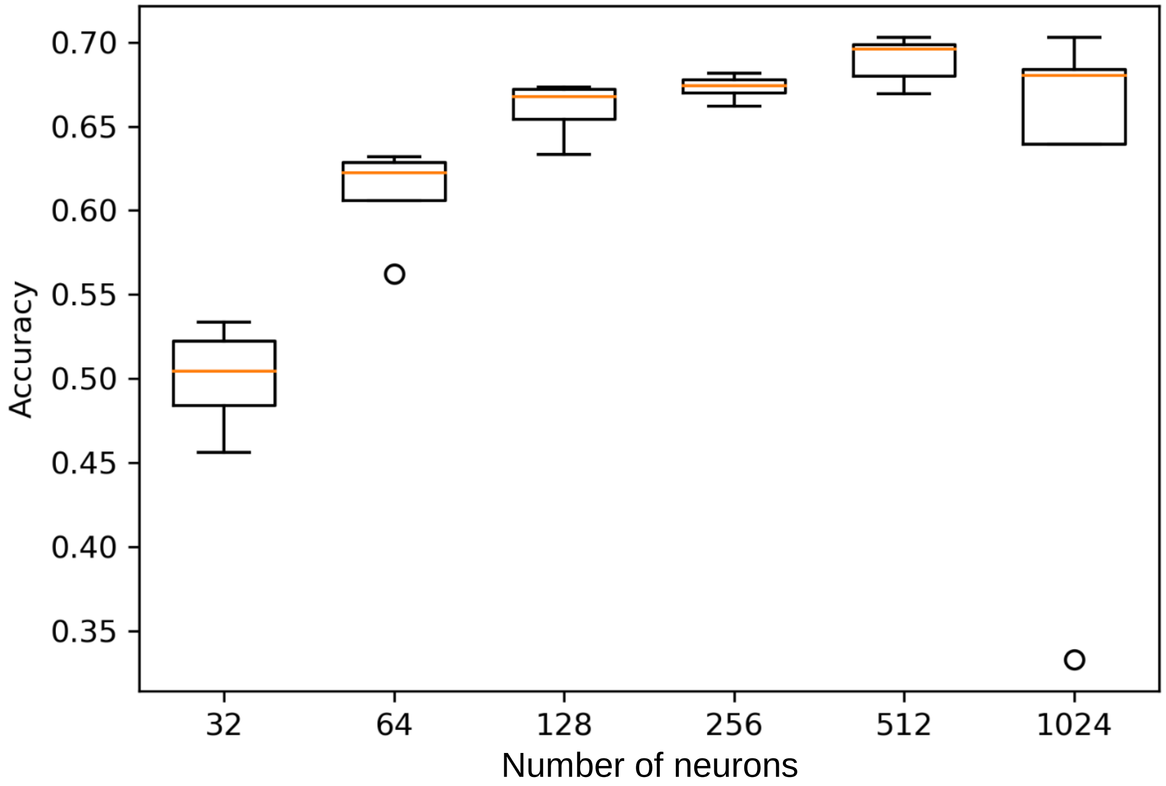
- Grit: suitable for robot commands, unique motion paths, lab settings
- Montalbano: co-speech (more profound)

Dataset	Chalearn Montalbano	Tsironi GRIT
#classes	**20**	9
#observations	**13 342**	542
#participants	**48**	6
#scenes	**5**	1

CNNLSTM – Upscaling



Avg. of 5 trials



Avg. of 5 trials

CNNLSTM – Upscaling

- Two Issues (Hypotheses):
  - *It is challenging for the CNNLSTM model to distinguish classes with similar movement patterns.*
  - *It is challenging for the CNNLSTM model to distinguish subtle movements done at the peak of the gesture.*
- **Solution:** *Snapture* architecture

3. How to identify the peak of the gesture and extract the handshape using RGB data only?

Gesture phases (Kendon)

1. Rest position

2. Pre-stroke

3. Stroke

4. Post-stroke

5. Rest position

Motion Profile

- **Problem:** analysis of motion/pause carried in a movement sequence
- **Solution:** structure similarity (SSIM) index

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}$$

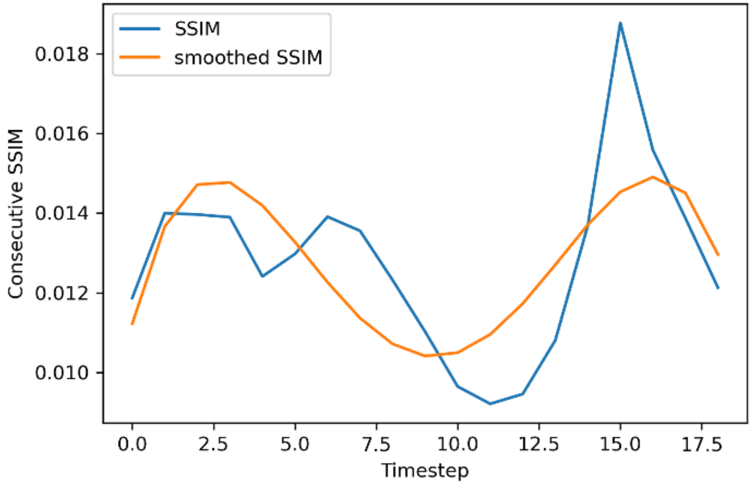
$$inverted_{SSIM} = 1 - \sum SSIM(\Delta_i, \Delta_{i-1})$$

$$\Delta_i = (I_i - I_{i-1}) \wedge (I_{i+1} - I_i)$$

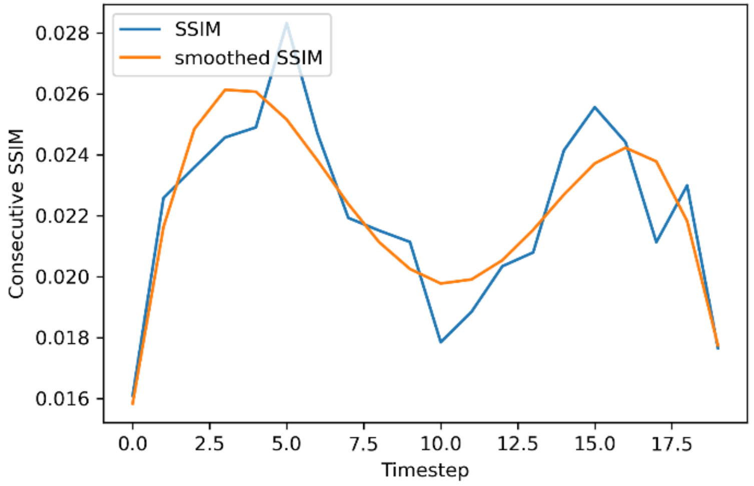
μ: avg. intensity, σ^2 :variance
C_1, C_1: stability constants
Δ_i, Δ_{i-1}: differential images
I_{i-1}, I_i, I_{i+1}: original frames

Motion Profile

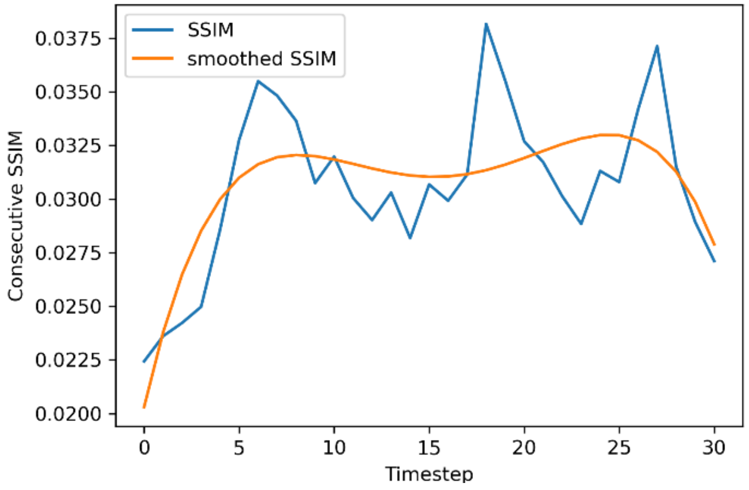
- Tsironi GRIT data:
  - *paused-gestures:* the arm remains briefly in a fixed position at the peak
  - or gestures with *repeated-pattern:* include a motion pattern, usually circular



Stop



Turn Left

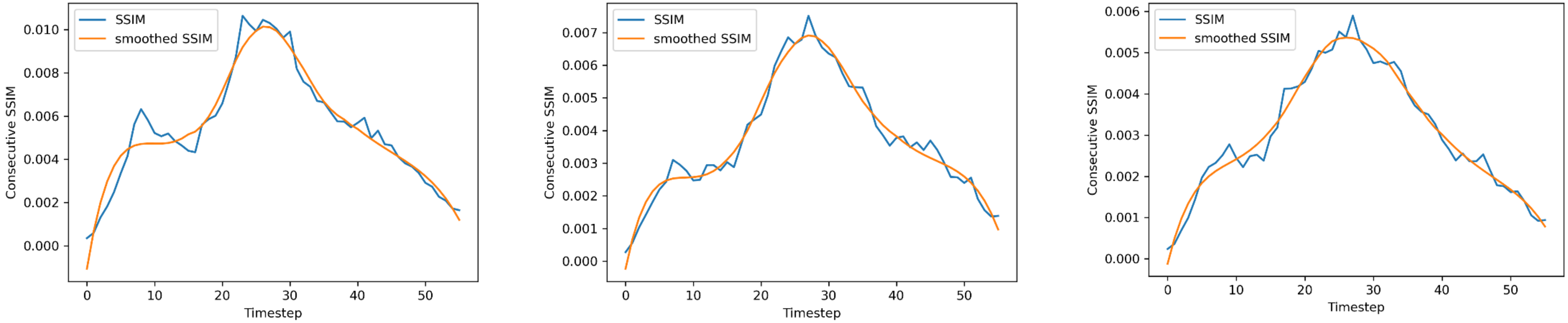


Turn

Motion Profile

- Chalearn Montalbano movements have comparable profile with pause at the peak

  → Peak around the mean of the sequence length



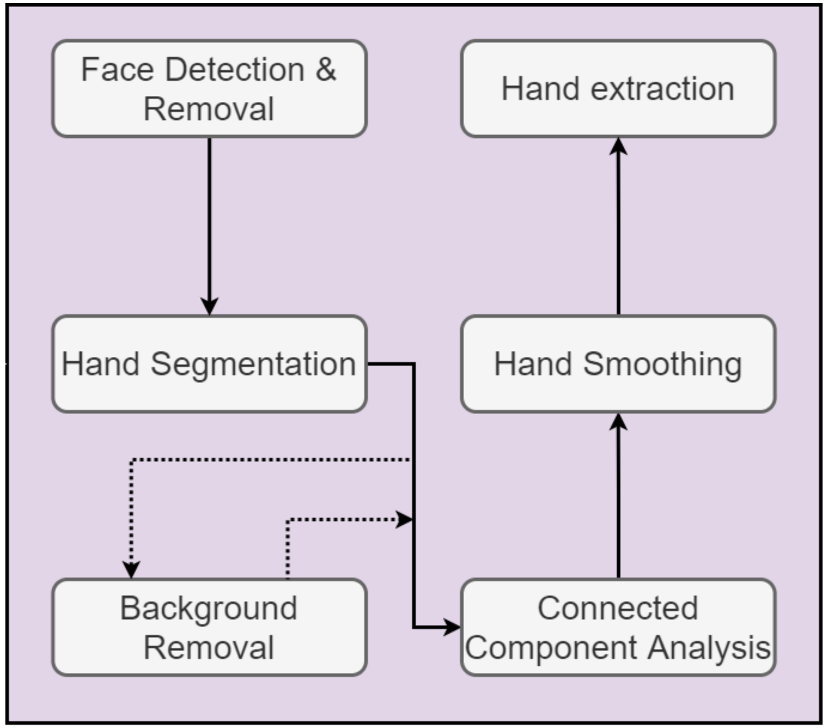
Vattene Vieniqui Ok

Snapture Architecture

Static Channel

- Gesture Peak Detection
- Gesture Peak Extraction

Frame at the peak of the gesture

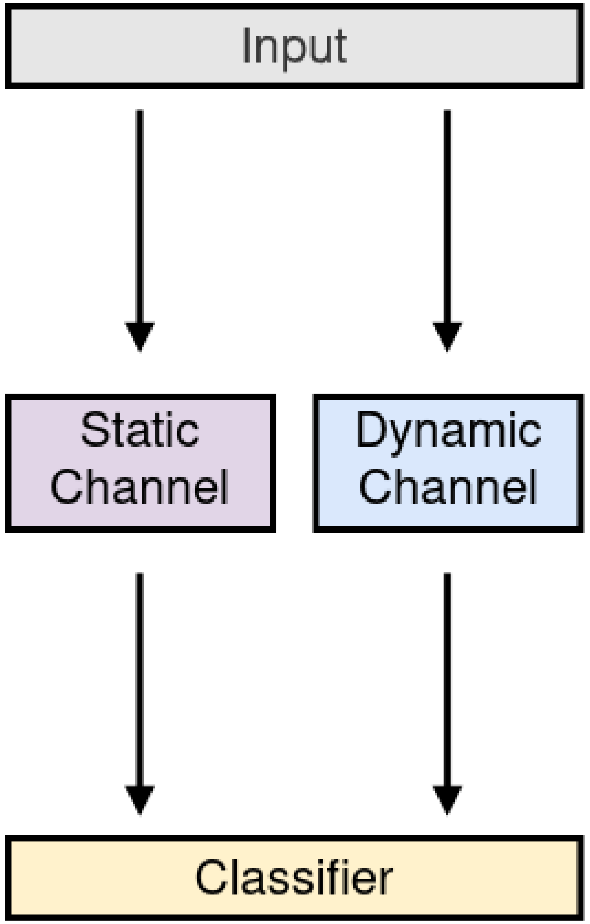


Snapshot Extraction

- Independent of subject's dominant hand

Snapture Architecture

- SNAPshot capTURE is our proposed architecture
- Hybrid (static/ dynamic) gesture recognition
- **Input:** *isolated sequences*



Snapture Architecture

Dynamic Channel

sequence-level CNNLSTM

Freganiente

Ok

Noncenepiu

Static Channel

a *snapshot* at the peak, CNN-based

4. How to regulate the integration of the hand details into a dynamic gesture recognition system?

- Some gestures, e.g., *Circle* are strictly dynamic .
- Low camera frame-rate

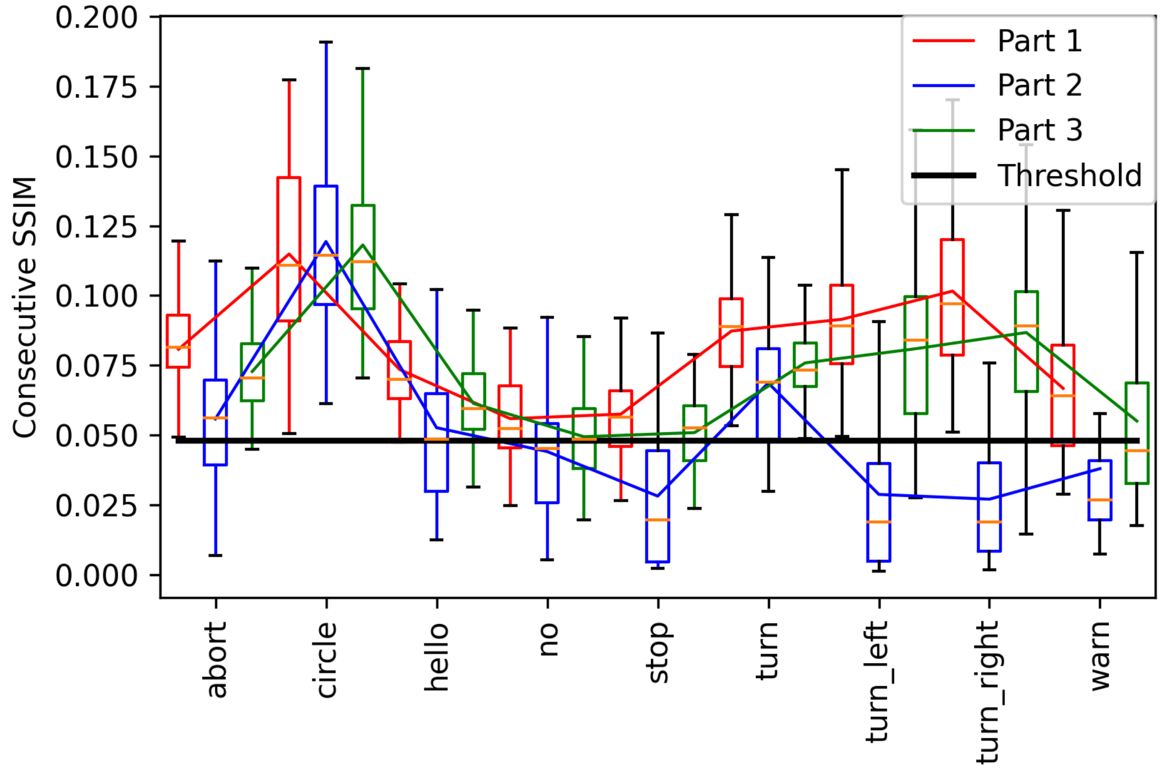
  → *blurriness* issue
- **Solution:** *threshold-controlled* approach based on sufficient pause

Circle

Stop

Regulating the static channel

- Lower values represent longer pauses.
- More pronounced for Stop, Turn Left and Turn Right
- Approx. only 44% of the GRIT samples include a pause

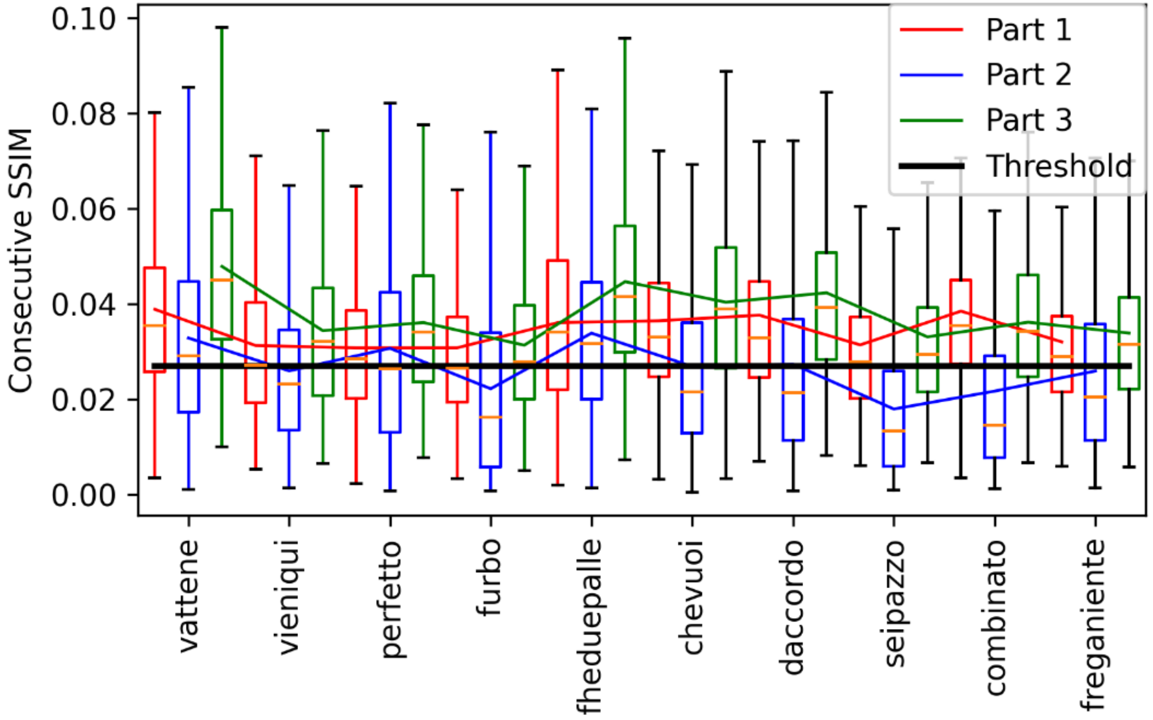


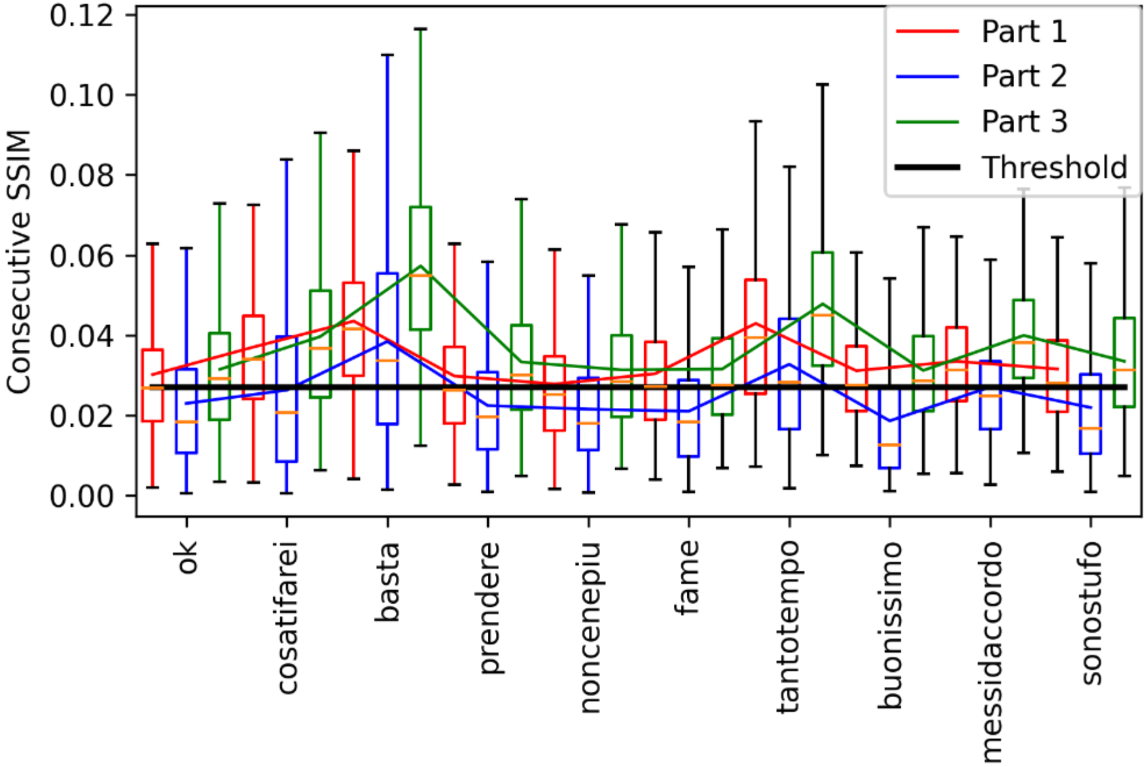
Part 1: rest to pre-stroke, Part 2: pre-stroke to post-stroke, Part 3: post-stroke to rest

Regulating the static channel

- Co-speech movements include more pause at the peak (approx. 70% of the Montalbano samples).

Part 1: rest to pre-stroke, Part 2: pre-stroke to post-stroke, Part 3: post-stroke to rest





Results

Tsironi GRIT Dataset

Model	Accuracy	F1-score	Time*
CNNLSTM	0.91 (0.012)	0.913 (0.012)	140.612 (0.255)
Snapture	0.924 (0.006)	**0.927** (0.005)	170.012 (1.027)
Snapture $_{thold}$	**0.926** (0.008)	0.913 (0.012)	125.156 (1.117)

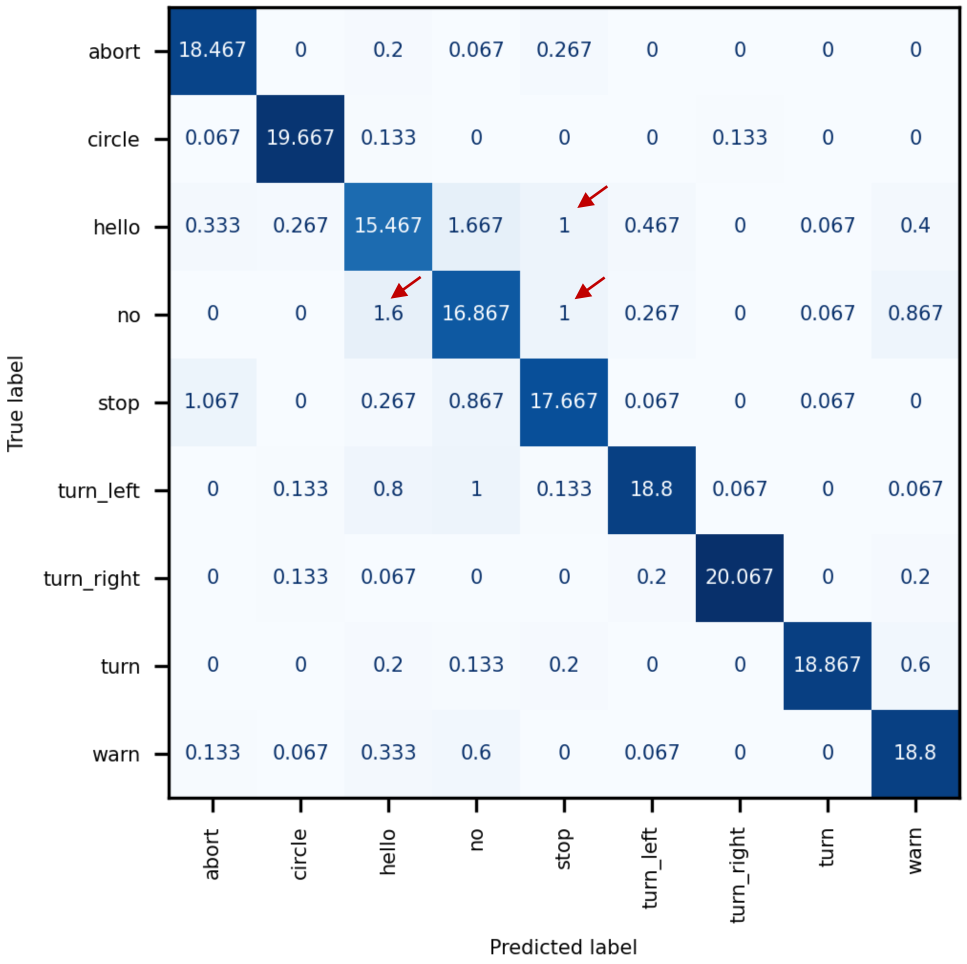
***In seconds.**

Chalearn Montalbano Dataset

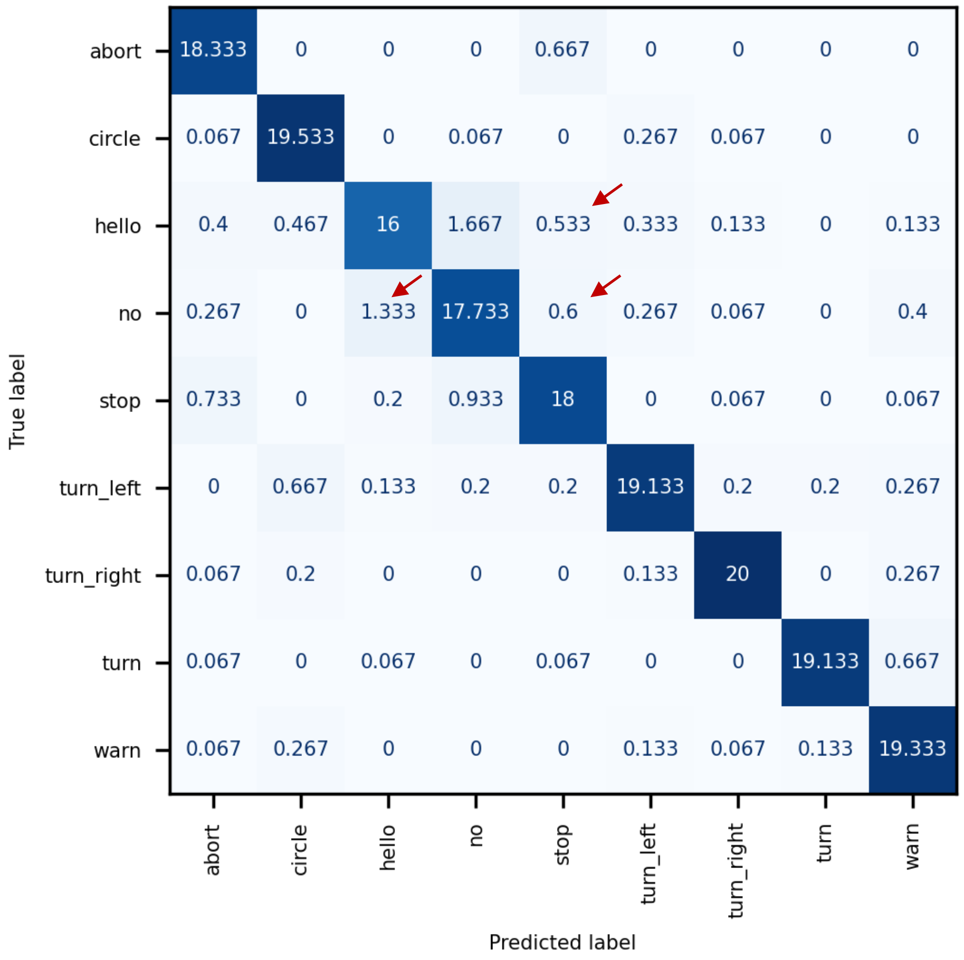
Model	Accuracy	F1-score	Time*
CNNLSTM	0.699 (0.014)	0.701 (0.013)	234.762 (0.115)
Snapture	0.755 (0.021)	0.752 (0.021)	318.578 (0.428)
Snapture $_{thold}$	**0.77** (0.008)	**0.772** (0.007)	744.953 (0.724)

***In minutes.**

Results Analysis - GRIT



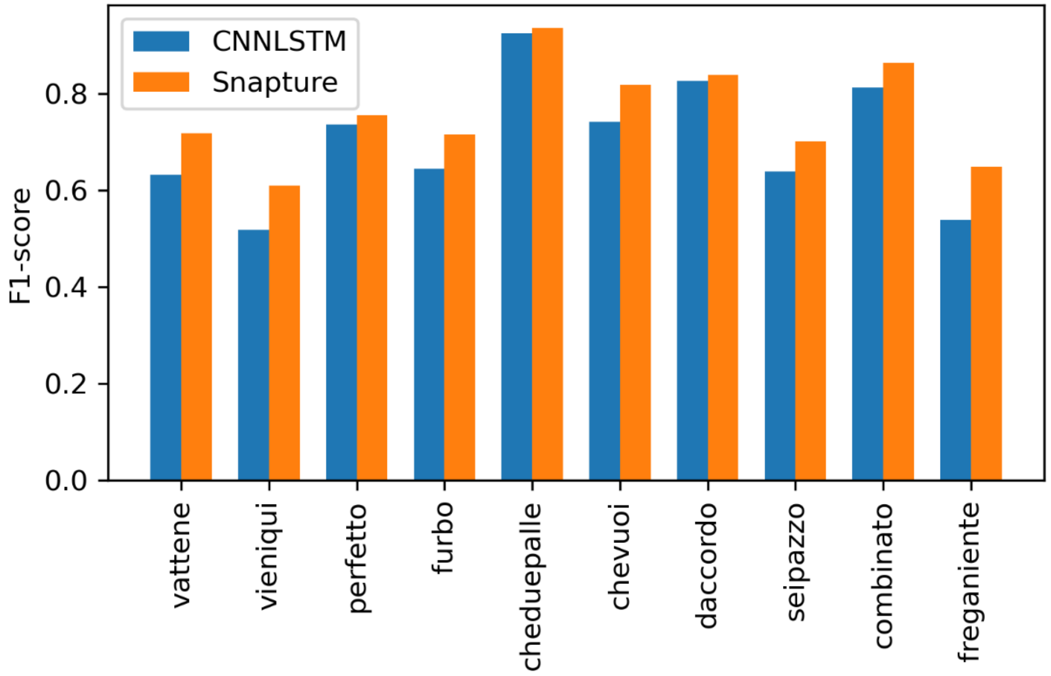
CNNLSTM
(avg. 5 trials)

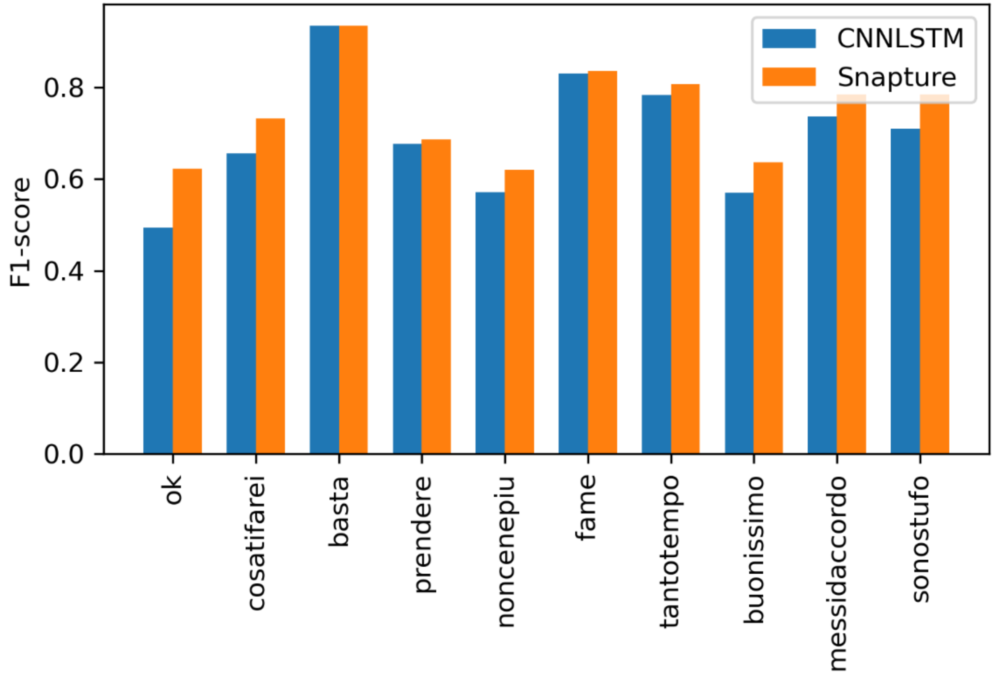


Snapture
(avg. 5 trials)

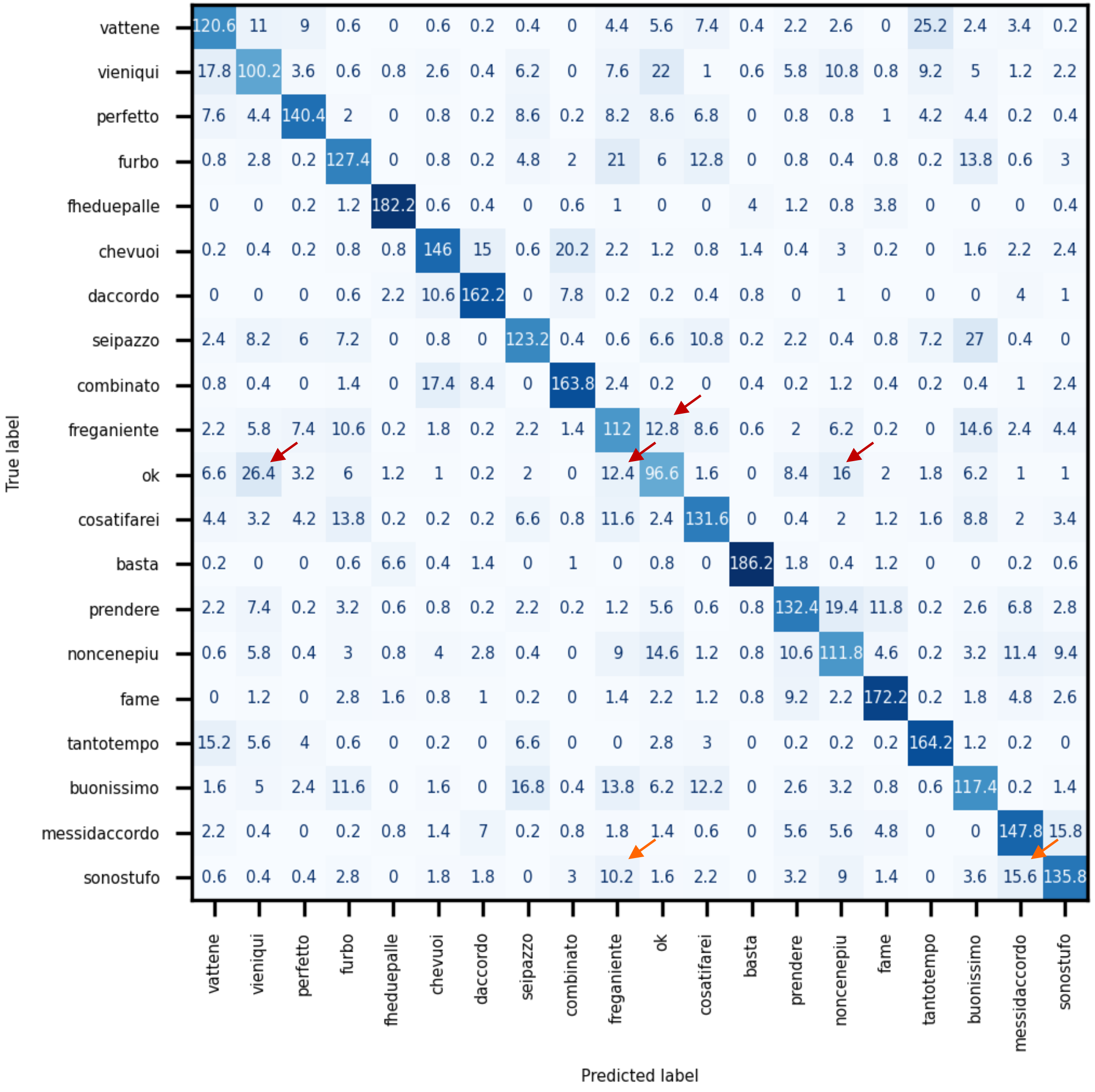
Results Analysis - Montalbano

- *Snapture:* superior results on all classes except for *Basta*
- Boosted F1-score for unique handshape classes (ex: *Ok*)

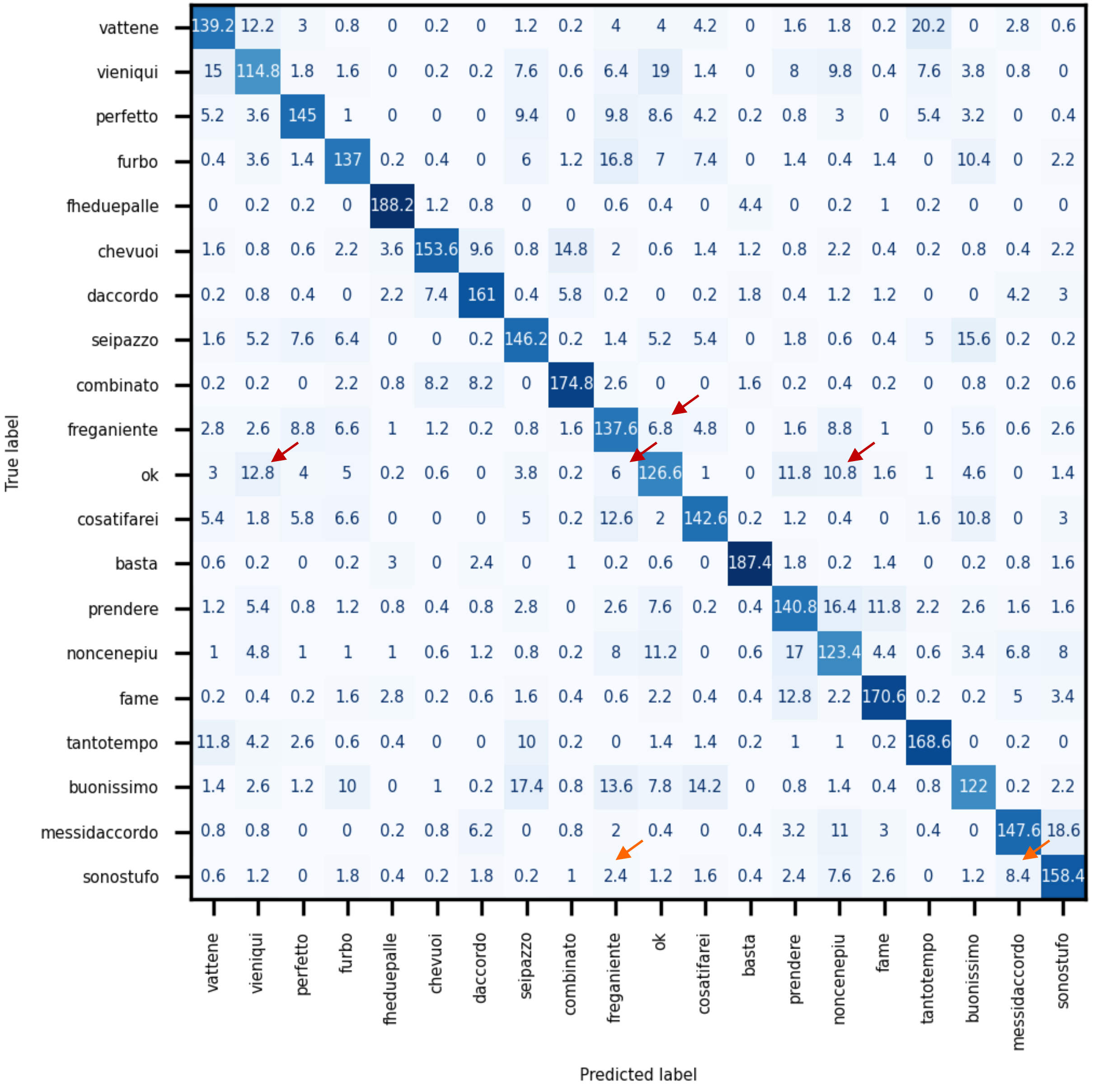




Results Analysis - Montalbano



CNNLSTM (avg. 5 trials)



Snapture (avg. 5 trials)

Results Analysis - Montalbano

- *Snapture* boosts the classification of indistinctive movements.






Cosatifarei | Vattene | Perfetto | Freganiente | Ok | Noncenepiu






snapshot | *snapshot* | *snapshot* | *snapshot* | *snapshot* | *snapshot*

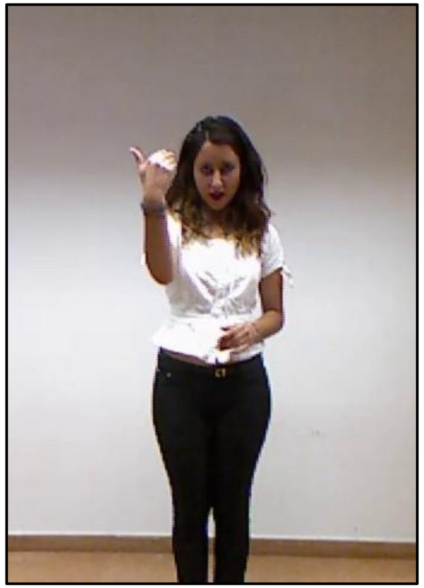
Results Analysis - Montalbano

- *Snapture* boosts the classification of subtle movements.

Basta (explicit hand movement

Sonostufo (subtle hand movement)

Results Analysis - Montalbano



Vieniqui or *Tantotempo*?

snapshot

snapshot

Furbo or *Buonissimo*?

snapshot

snapshot

Conclusion

How influenced is the CNNLSTM network by subject variability?

- Network's limitation when presented with data of new subjects

  → Train *Snapture* on data from all participants

  → Satisfactory solution in the context of our work (we analyzed architecture rather instead of comparing to benchmark)

Conclusion

How efficient is the CNNLSTM network at learning co-speech gestures?

- Network's limitation
  - Main issues: similar motion patterns, missing hand details (pre-processing)

- Our *Snapture* architecture achieved superior results to CNNLSTM due to the static channel

Conclusion

How to identify the peak of the gesture and extract the handshape using RGB data only?

- Our algorithm worked well under the Kendon's model assumption.
- Independent of the hand
- Future work: additional channels (facial features, speech, body pose)

  → simple (modularity of our architecture)

Conclusion

How to regulate the integration of the hand details into a dynamic gesture recognition system?

- *Snapture* $_{thold}$ bypassed the *blurriness issue and improved* the performance of *Snapture even further.*
- Future work: improve robustness of threshold values.

Thesis Contribution

- Thorough analysis of Tsironi GRIT and Chalearn Montalbano gestures
- New architecture proposal: *Snapture* (code available soon).
  - Emblematic gestures & co-speech domains.
- New algorithm based on SSIM for analyzing a gesture's motion profile and identifying its pause.
- Montalbano temporal segmentations (publicly available soon).
- A concrete step to support an immersive HRI scenarios without the lab restrictions.

The End

Thank you for your attention.

Any question?

Literature

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