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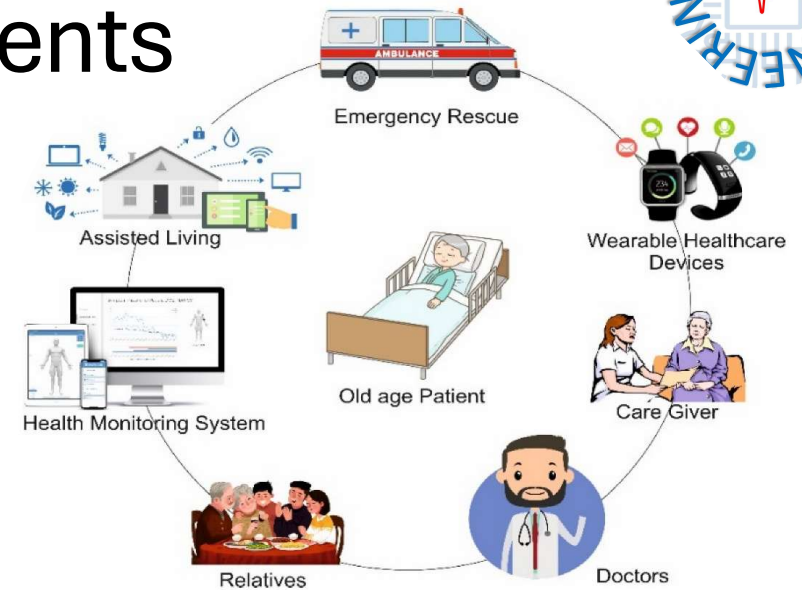
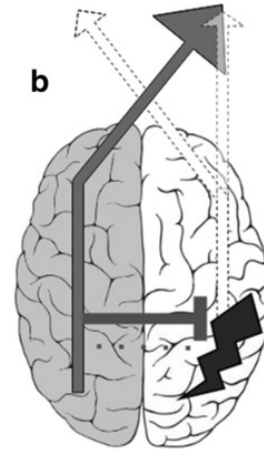
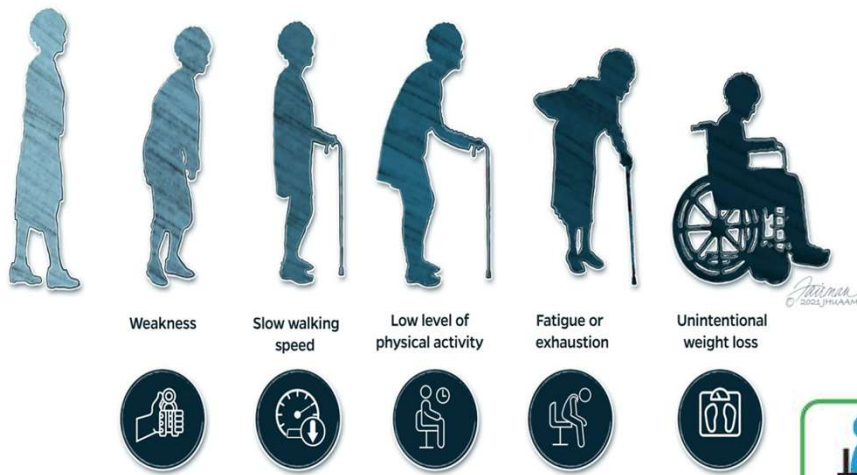
# Quantitative analysis of rehabilitation protocols based on Kinect Azure data: a feasibility study

Presented by:

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ZüMüTü 2025

# Monitoring ADL and rehabilitation in frail individuals and neurological patients



- Neurological conditions and frailty can compromise individual's independence.
- Musculoskeletal abilities are often compromised.

- Remote monitoring and assistance are crucial for frail people recovery and support
- Activities of Daily Living are a significant index for individual's independence

# Rehabilitation

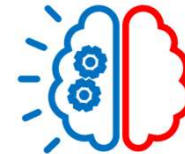
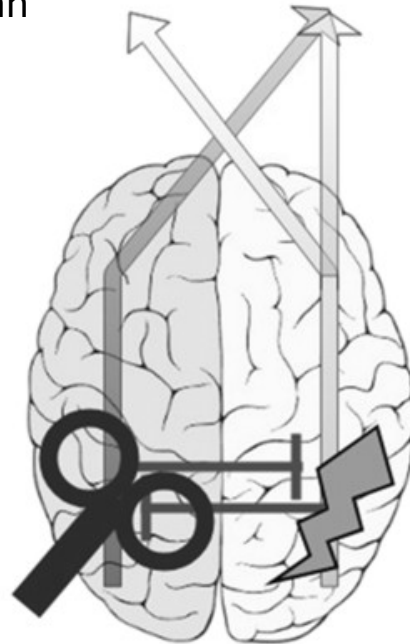
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Physical and neurological rehabilitation can improve health conditions by far.

Common approaches:

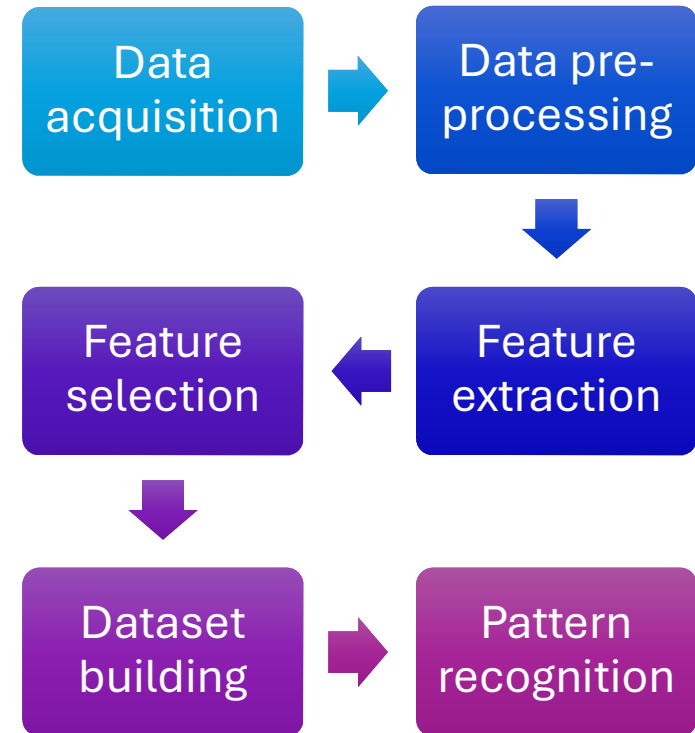
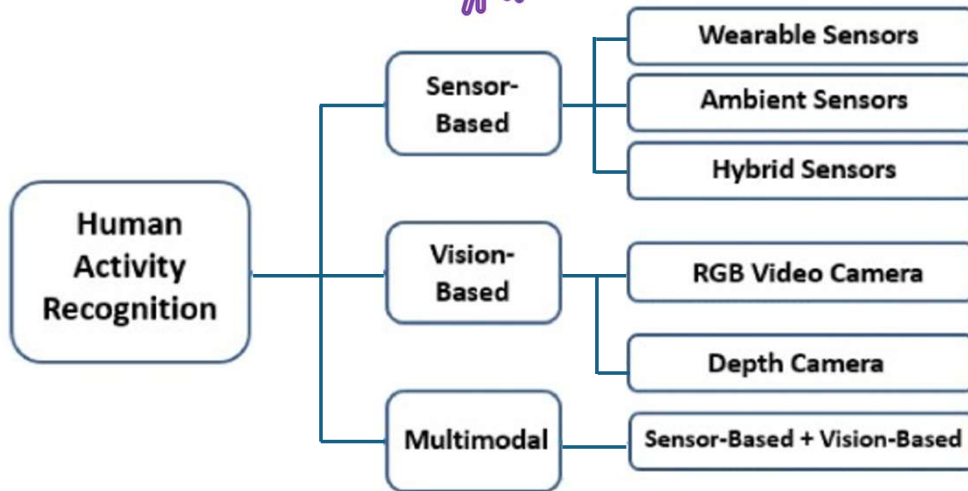
- Physical rehabilitation
- Occupational therapy
- Neuromotor rehabilitation

The improvement of health conditions is constantly monitored by clinicians.



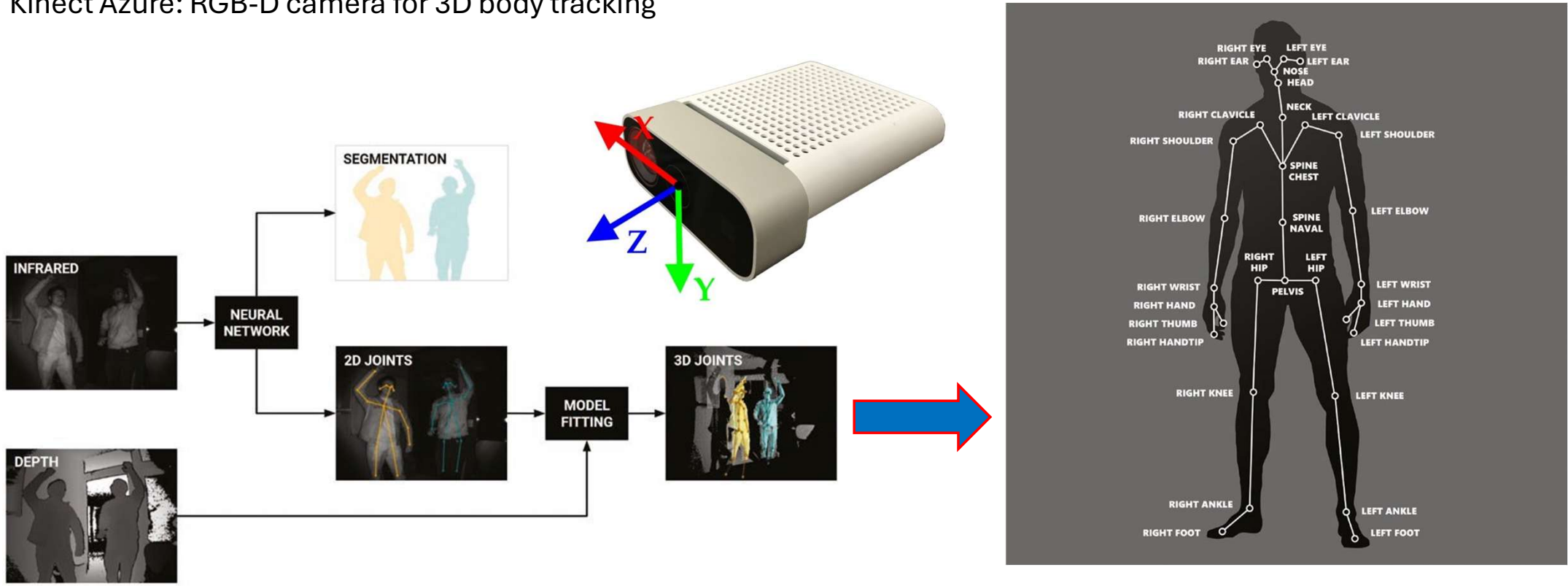
# Human Activity Recognition

- Gestures
- Actions
- Interactions
- Group of activities

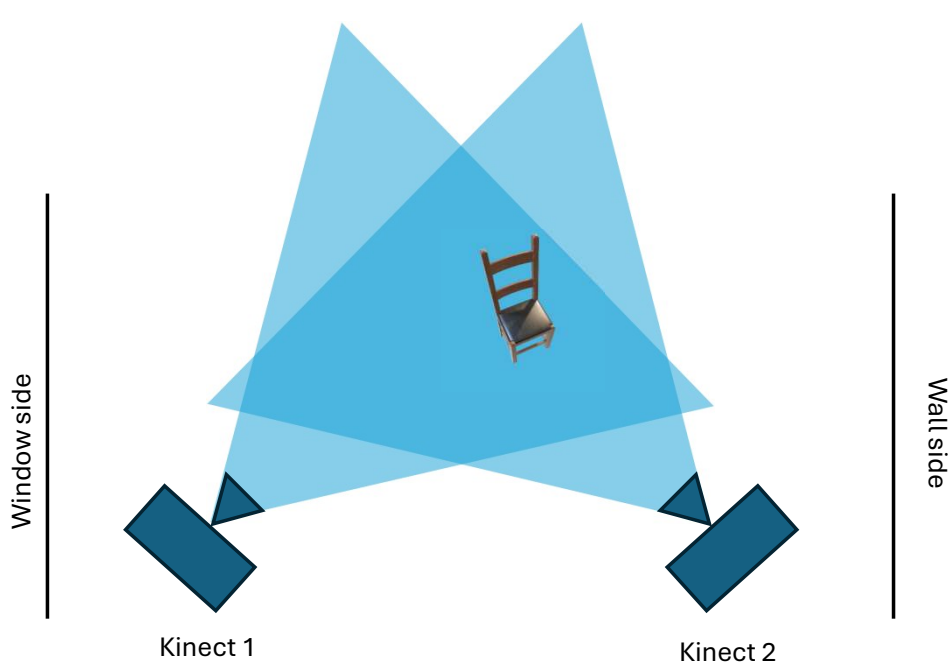


# Instrumentation

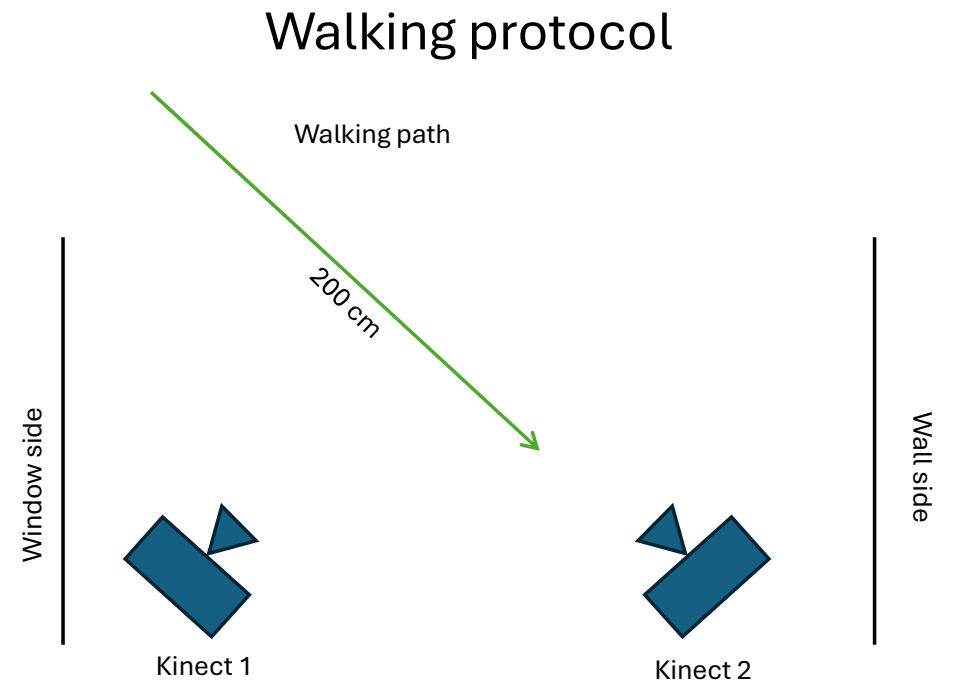
Kinect Azure: RGB-D camera for 3D body tracking



# Experimental setup



Rehabilitation and ADL protocol

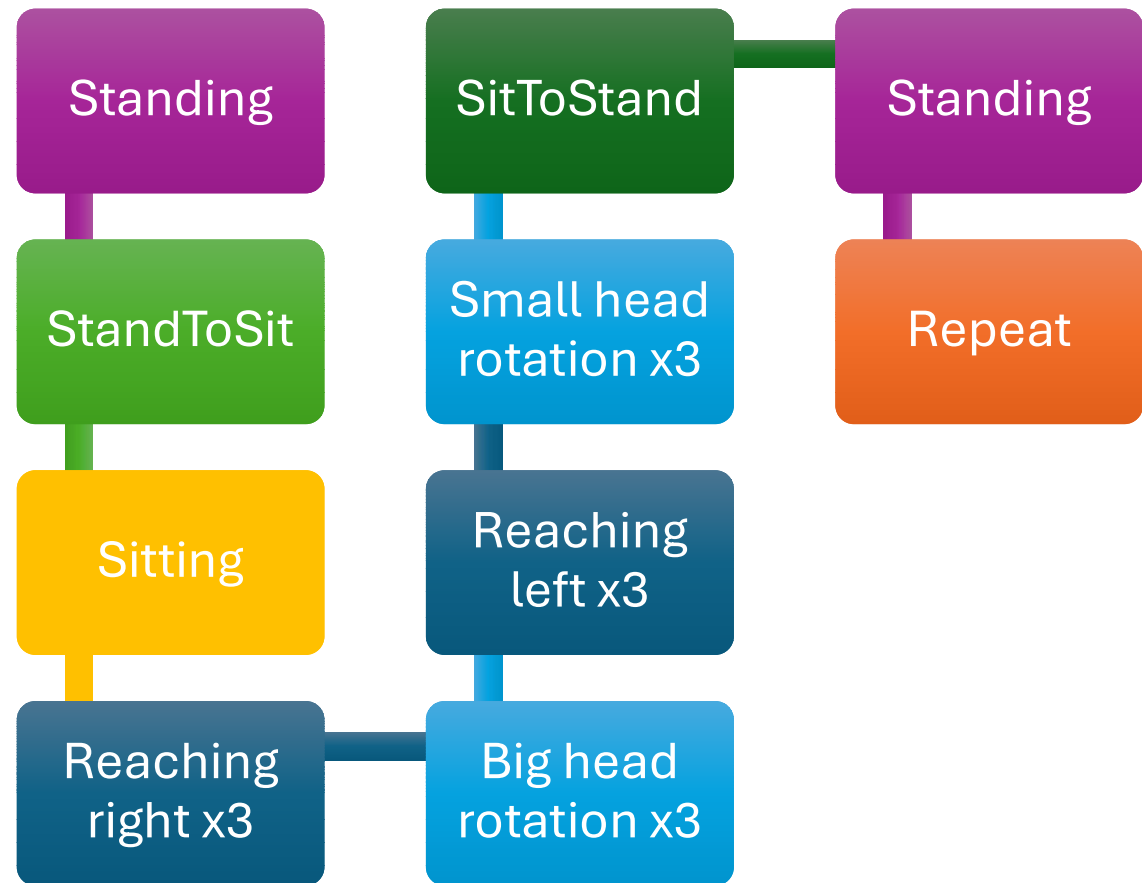


Walking protocol

# Protocol

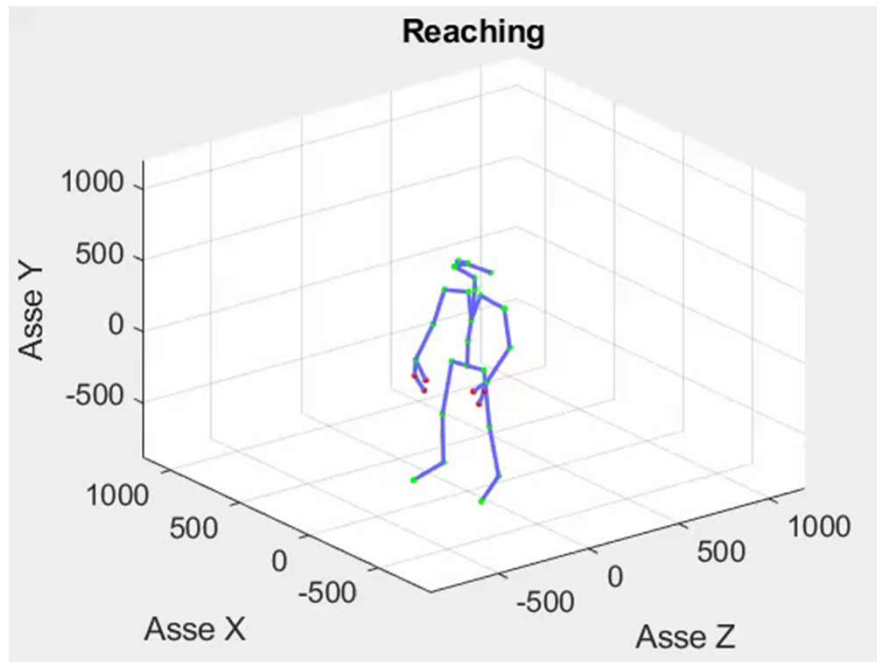
## Protocol activities

- Standing: 0
- Sitting: 1
- SitToStand: 2
- StandToSit: 3
- Walking: 4
- Reaching: 5
- Head rotation: 6
- Hand Rise: 7



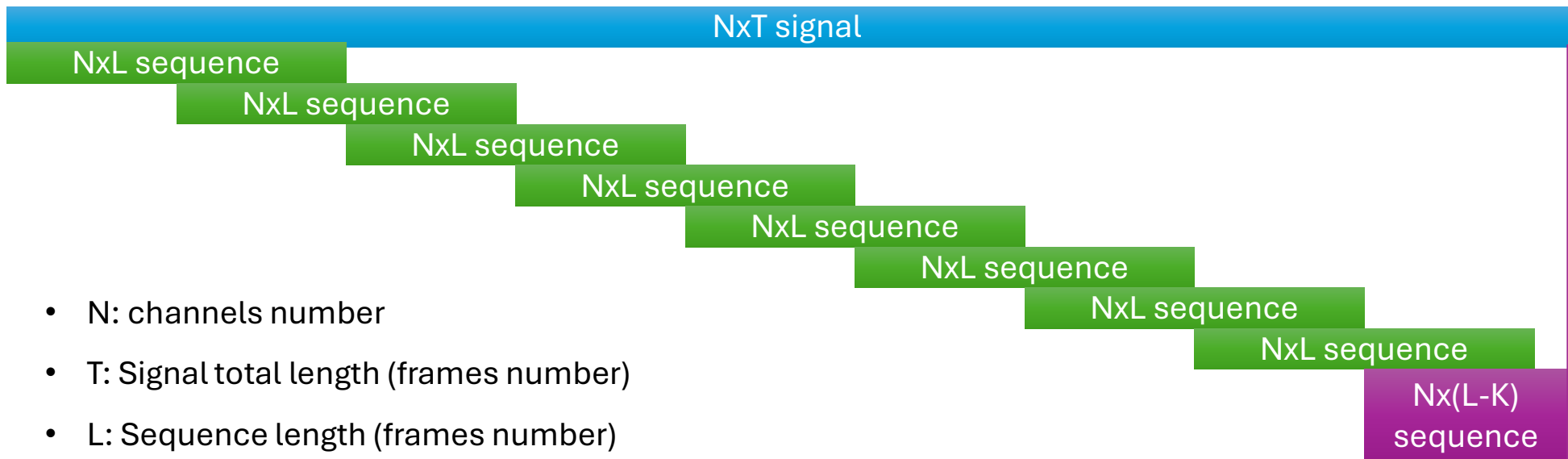
# Data representation

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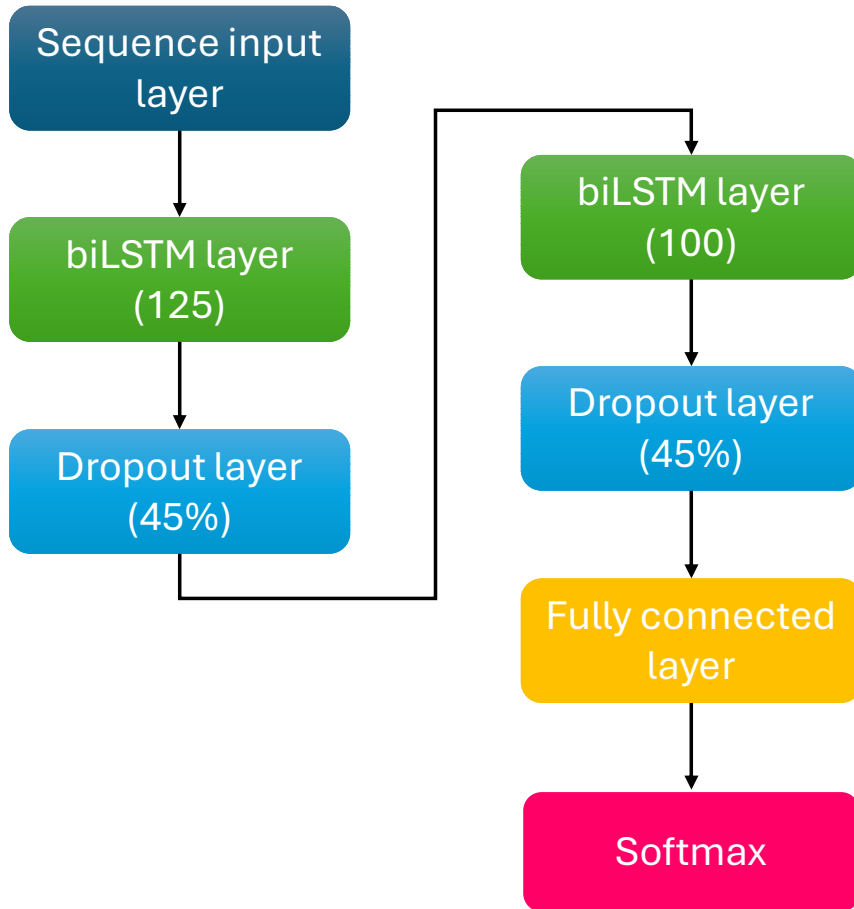


# Dataset preparation



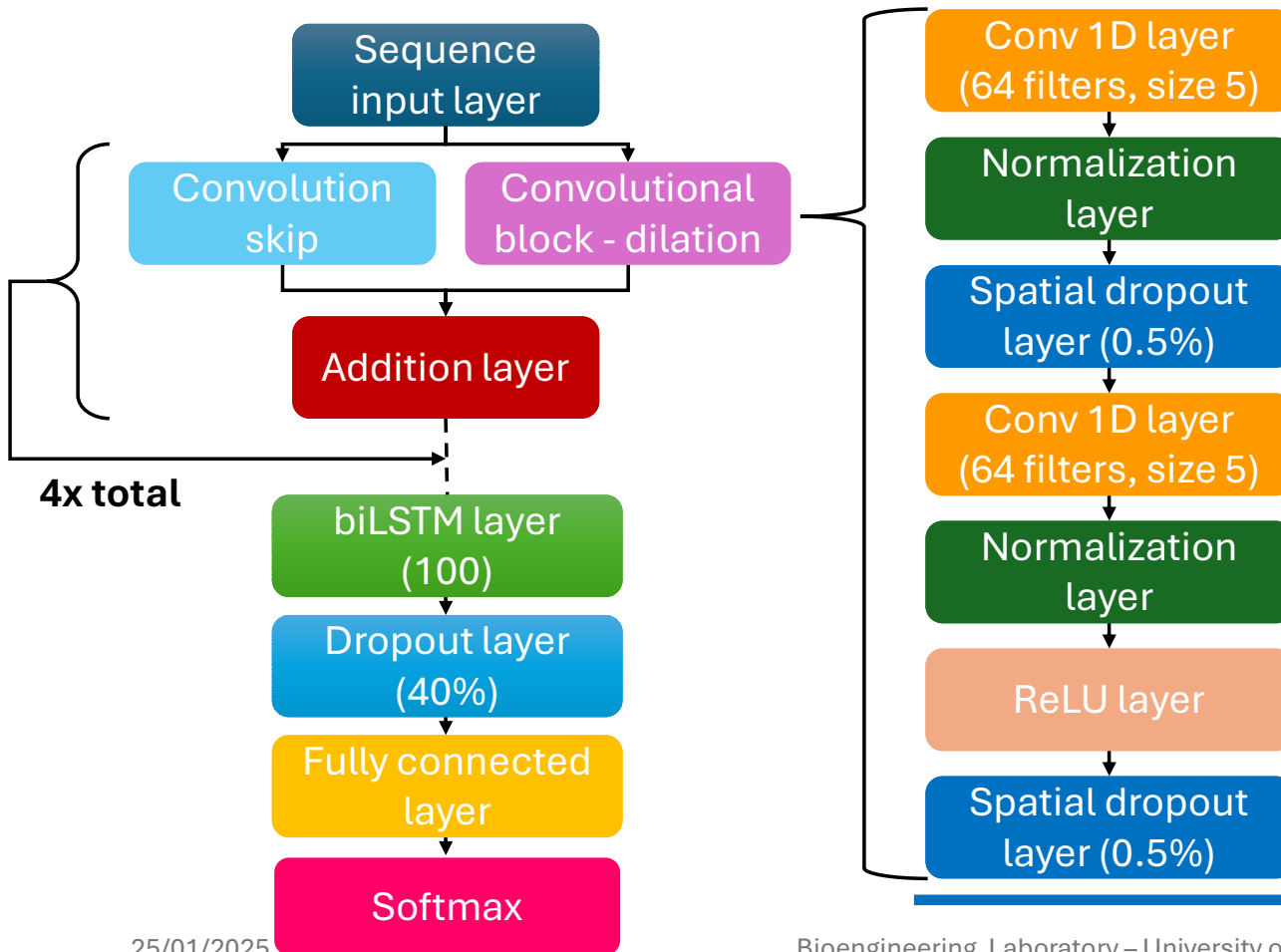
- N: channels number
- T: Signal total length (frames number)
- L: Sequence length (frames number)
- K: Residual samples

# Neural Network model: 2BILSTM2D



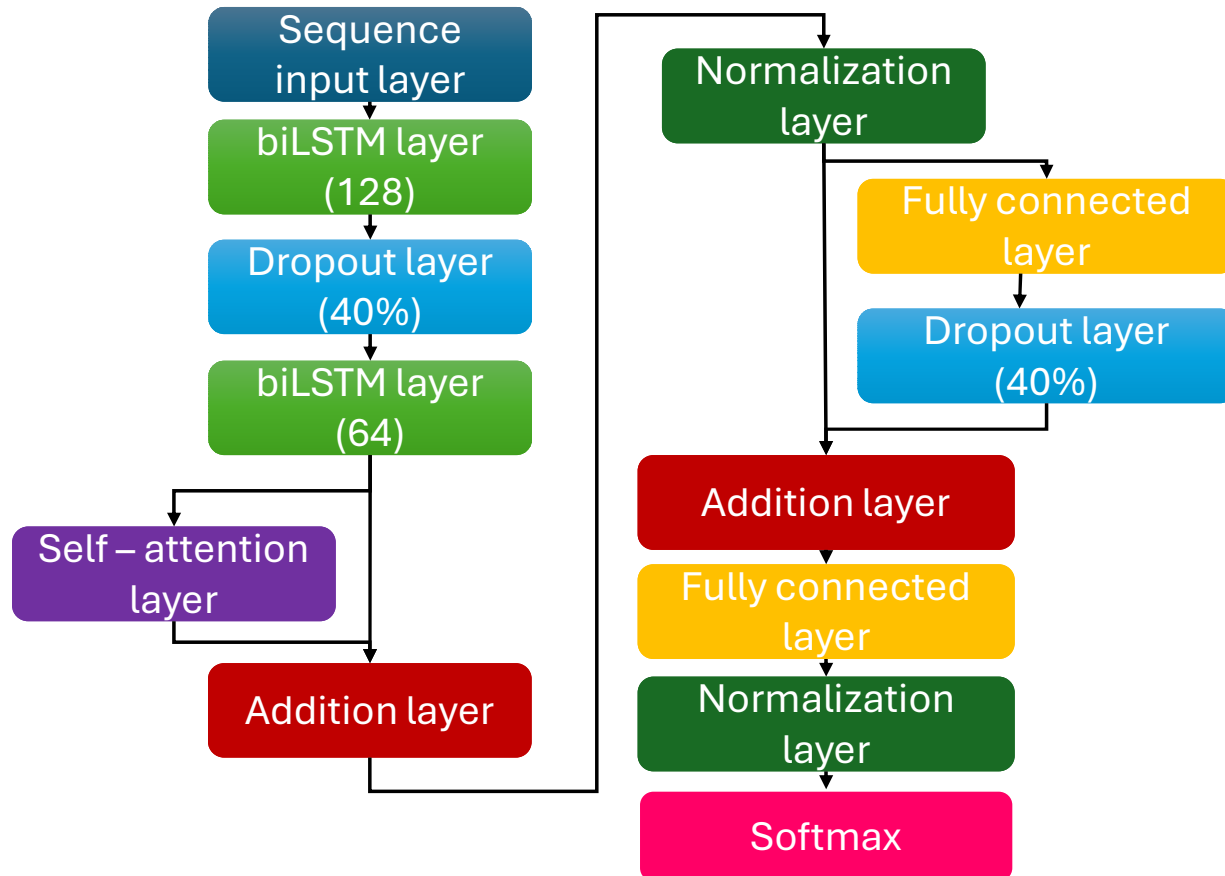
- **Name:** 2BLSTM2D
- **Number of parameters:** 477.4k
- **Loss Function:** Crossentropy
- **Number of Epochs:** 200
- **Stop criteria:** «Validation patience» = 10
- **Memory usage:** 1.82 MB

# Neural Network model: TCN – skip connection



- **Name:** TCN – skip connection
- **Number of parameters:** 171.9k
- **Loss Function:** Crossentropy
- **Number of Epochs:** 200
- **Stop criteria:** «Validation patience» = 10
- **Memory usage:** 0.66 MB

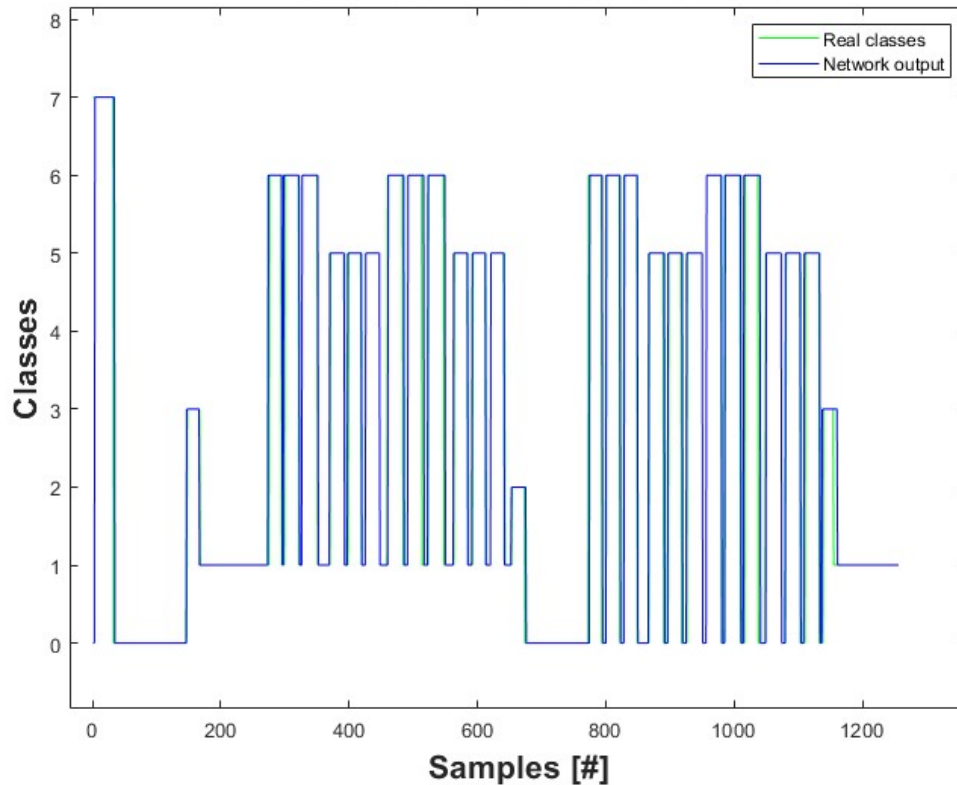
# Neural Network model: attention based BLSTM



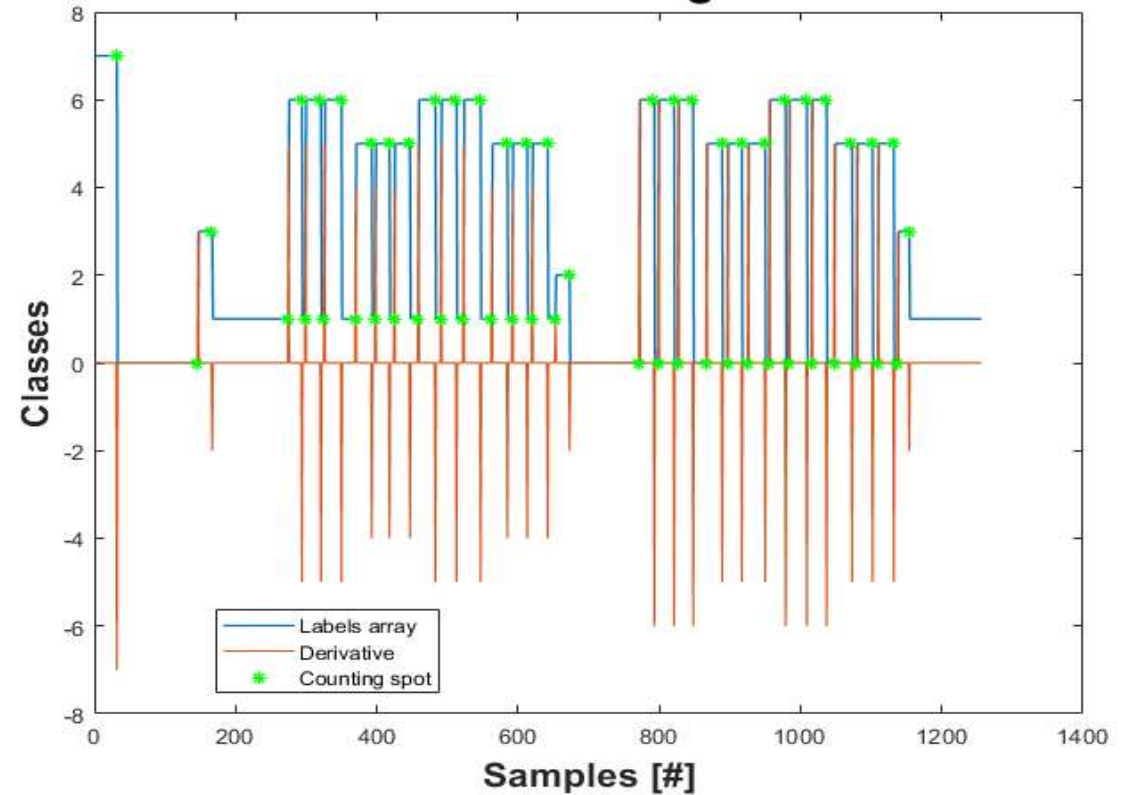
- **Name:** TCN – skip connection
- **Number of parameters:** 456.3k
- **Loss Function:** Crossentropy
- **Number of Epochs:** 200
- **Stop criteria:** «Validation patience» = 10
- **Memory usage:** 1.74 MB

# Network output and quantification

Net output VS Real classes

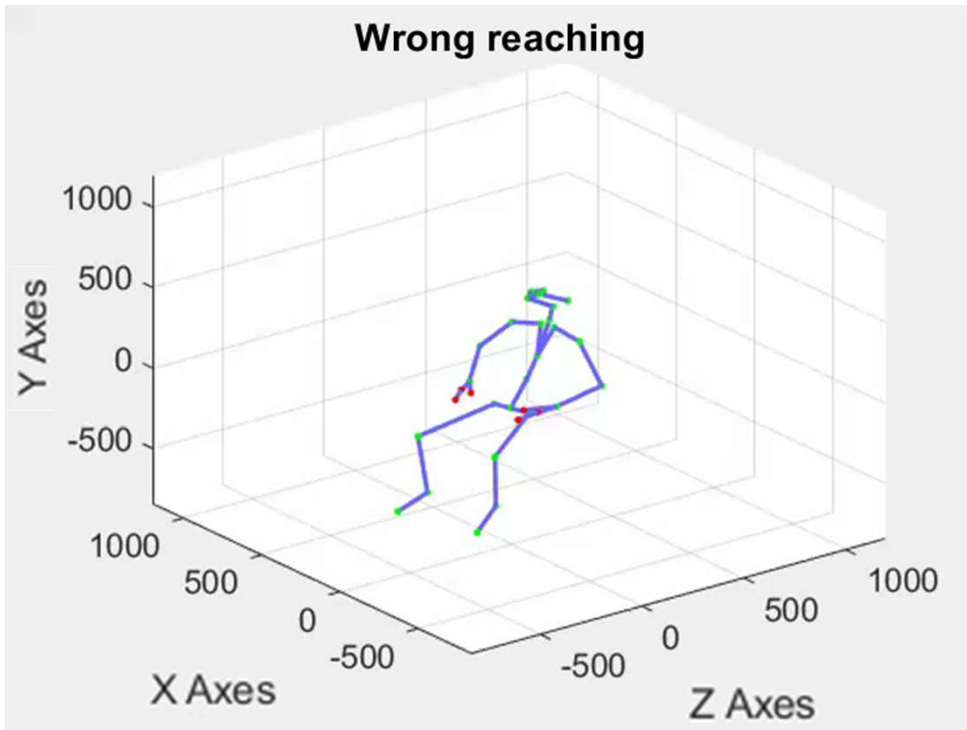


Quantification algorithm

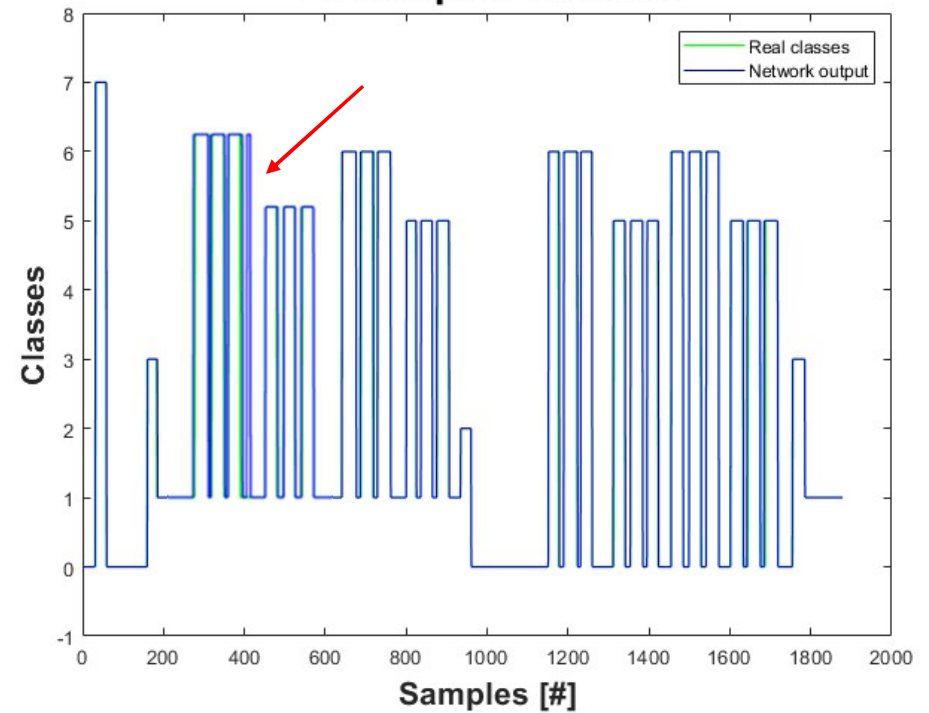


# Limits

Wrong reaching



Net output mistakes



Class	Real count	Estimated count
Head rotation	12	13 ❌

# Model optimization

Starting net

Hyperparameters set for BLSTM: [125 100]  
Accuracy: 94.3%, starting parameters number: 477.4k

Hyperparameter optimization using Bayesian method

Target metric: penalized accuracy (accuracy –  $10^{-4}$ \*weights number)

Trade off between performance and net weight (Score to maximize)

Score metric: Accuracy delta [%] + parameter cost  
Accuracy delta: Accuracy best net [%] – accuracy of candidate net [%]

Detailed grid search around trade off network

Parameter cost =  $\frac{2}{1+e^{kX}} - 1 \rightarrow k = 0.05$  sigmoid curve slope  
 $X = 100 \frac{\text{parameters number of best net} - \text{parameters number of candidate net}}{\text{parameters number of best net}}$

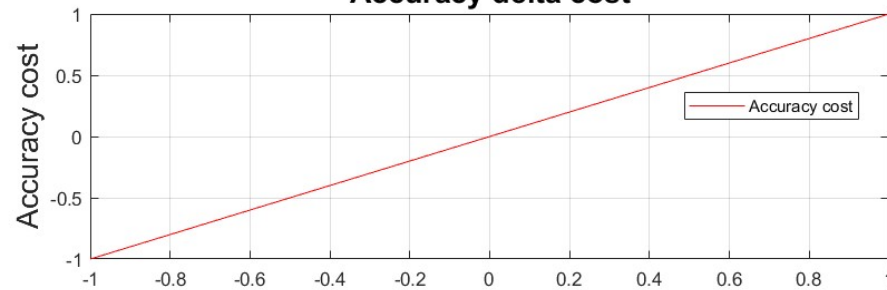
Trade off in new pool

Resulting hyperparameters set for BLSTM: [24 29]  
Accuracy: 93.7%, final parameters number: 36.6k

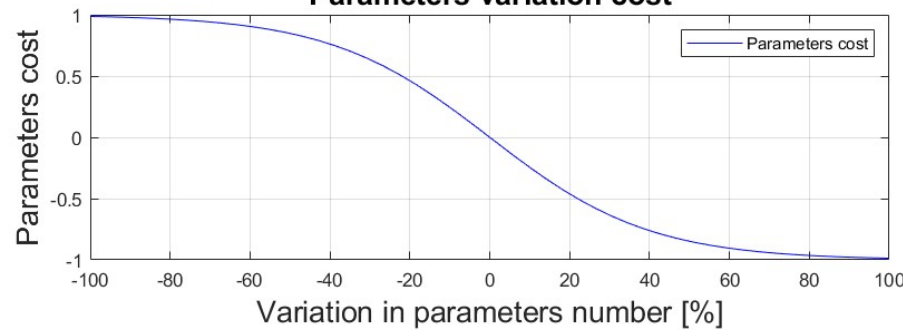
# Score function

Score function components

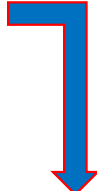
Accuracy delta cost



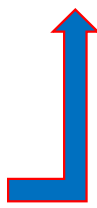
Parameters variation cost



$$X1 = X$$

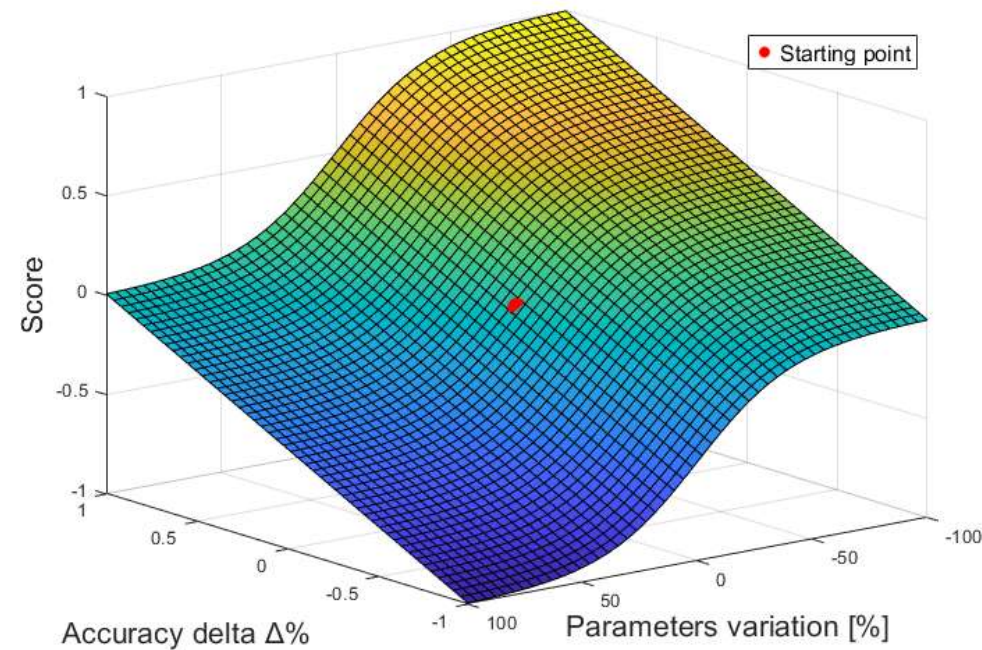


$$\frac{X1 + X2}{2}$$



$$X2 = \frac{2}{1 + e^{kX}} - 1$$

Score function







# Results

Model	Starting Hyperparameters set and <i>weights number</i>	Starting Accuracy	Final Hyperparameters set and <i>weights number</i>	Final Accuracy	Accuracy Variation $\Delta\%$	Parameters Variation %
2BLSTM2D	[125,100] 447400	93.7%	[34,16] 39432	94.4%	<b>+0.7%</b>	<b>-91%</b>
TCN	[4,64,5] 171976	91.6%	[2,42,2] 18728	92.8%	<b>+1.2%</b>	<b>-89%</b>
Attention	[128,64,2] 456374	94.7%	[42,18,1] 64431	94.8%	<b>+0.1%</b>	<b>-85%</b>
Attention reduced	[30,3] 78765	94.1%	[26,1] 37983	93.6%	-0.5%	<b>-51%</b>



# Conclusion

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## Take home results

- Prototype database for ADLs and rehabilitation.
- Automatic system for quantitative monitoring of frail individuals.
- Trade off score for neural networks evaluation.

## Future directions

- Database enhancement in terms of subjects and activities number.
- Improve net performance reducing output mistakes
- Real time implementation of HAR system for daily and rehabilitation monitoring.



# Thank you for the attention!