Identity and Posture Recognition from Pressure Maps with Inception-Based Deep Network

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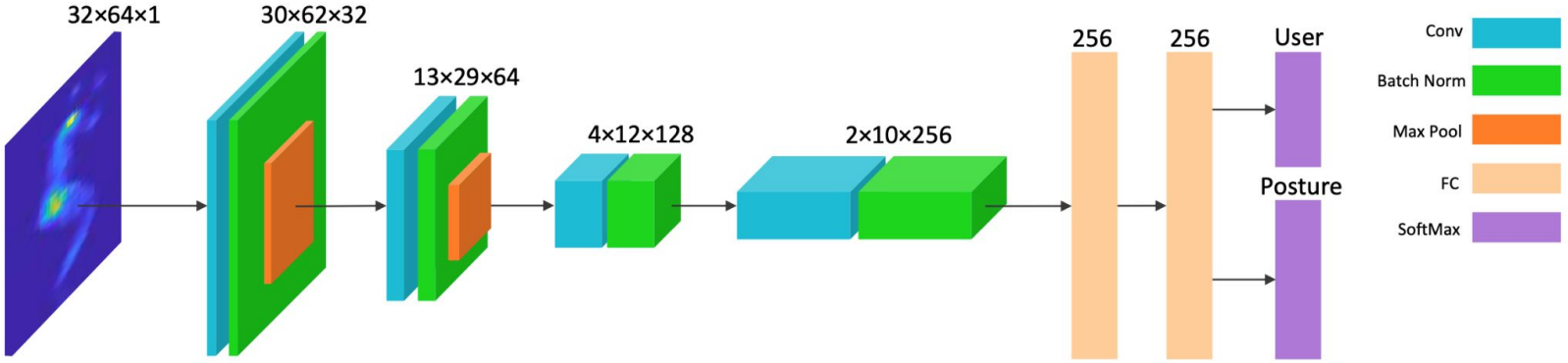
Previous Study

POSTURE RECOGNITION PRECISION (IN %).

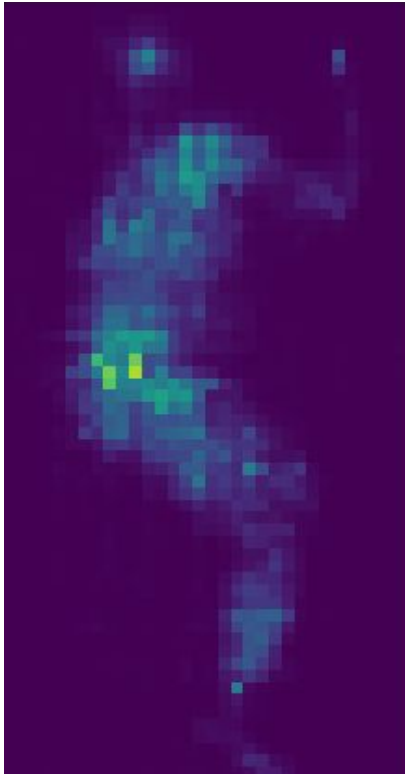
Validation Scheme	10-Fold			LOSO		
Posture	Supine	Right	Left	Supine	Right	Left
Quadratic SVM	99.3	98.6	99.7	81.2	64.3	64.3
kNN ($k = 10$)	99.9	99.6	99.9	75.6	46.1	54.3
Bagged Trees	99.8	99.9	99.9	90.6	54.0	65.0
Proposed method	**100**	**100**	**99.9**	**99.0**	**100**	**99.7**



[Davoodnia19] V. Davoodnia and A. Etemad, Identity and Posture Recognition in Smart Beds with Deep Multitask Learning, in Proceedings of the IEEE International Conference on Systems, Man and Cybernetics (SMC), Bari, Italy, 2019.

The Dataset: PmatData

- Pressure maps collected with Vista Medical Force Sensitive Application (FSA) Soft- Flex 2048, a commercial pressure-sensing mattress with 2048 sensors, distributed across a 64(height) x 32(width) grid
- 13 participants in 17 different in-bed postures
- 17 files for each subject, each one related to a specific posture
- Each file includes around 2 minutes of acquisitions
- 1 Hz sampling rate sensors
- Each sensor reports numbers in the range [0-1000]

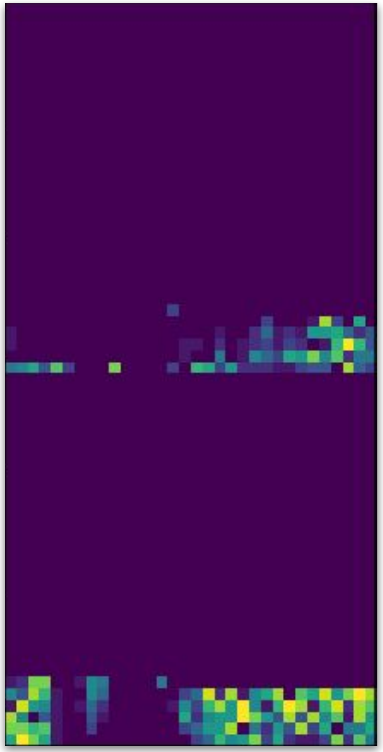


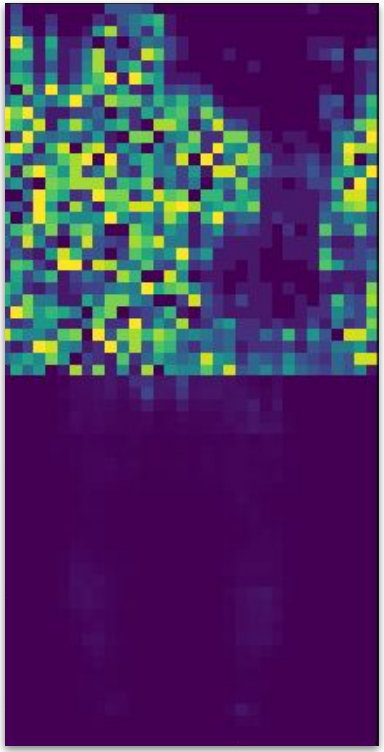
[Pouyan17] M. B. Pouyan, J. Birjandtalab, M. Heydarzadeh, M. Nourani and S. Ostadabbas, A pressure map dataset for posture and subject analytics, in Proceedings of the IEEE EMBS International Conference on Biomedical & Health Informatics (BHI), Orlando, FL, 2017.

Pre-Processing

Removal of not significant frames

- Artifacts are present in many images, caused by malfunctioning sensors outputting values greater than 1000. In particular, 2 frames contain more than 100 artifacts.
- 14 images (all coming from a subject in one single posture) are very noisy.
- The first and the last three images of each posture are very often not significant.





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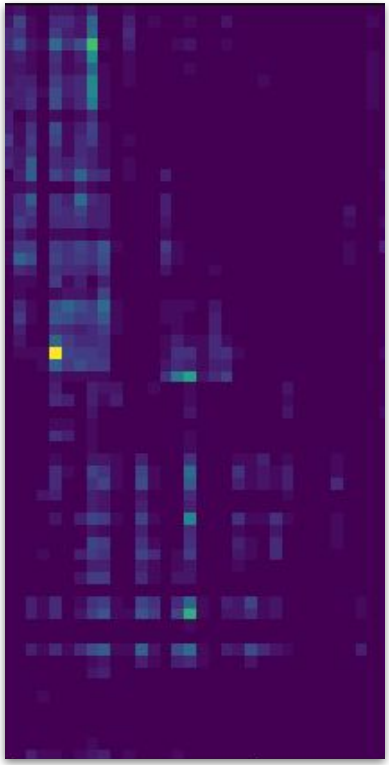

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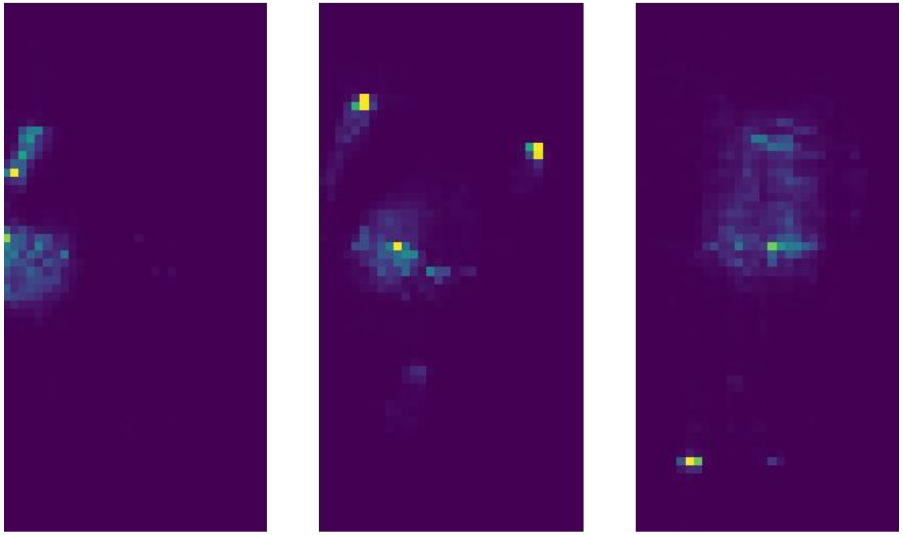


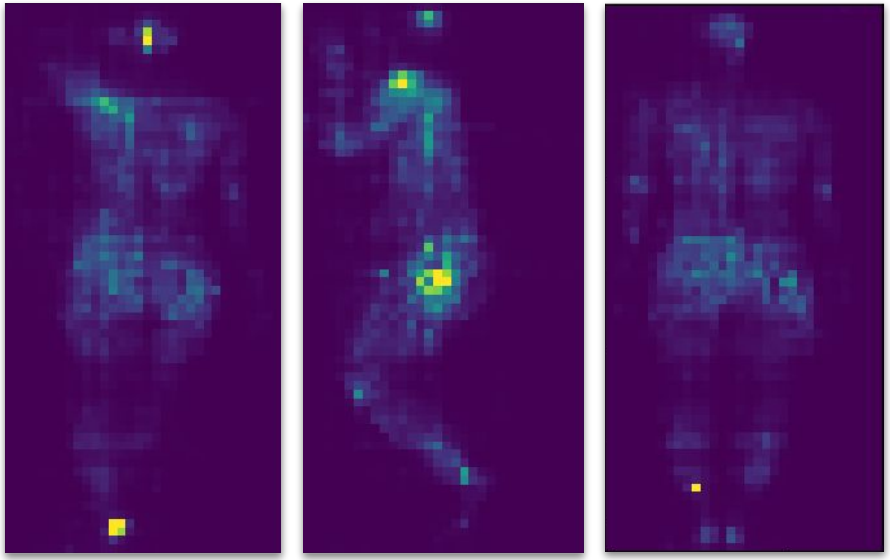
Pre-Processing

3x3x3 Median Filter Application

Many images contain a few artifacts.

This is healed by applying a spatio-temporal 3x3x3 median filter.

Then, images are normalized dividing by 1000.



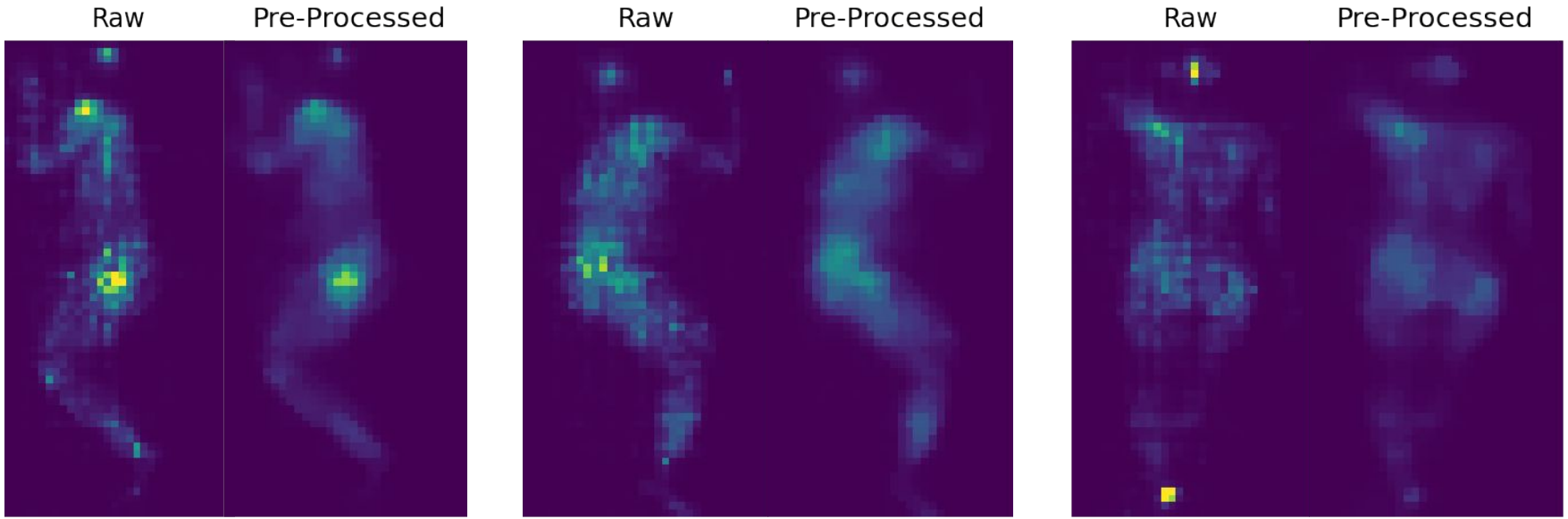


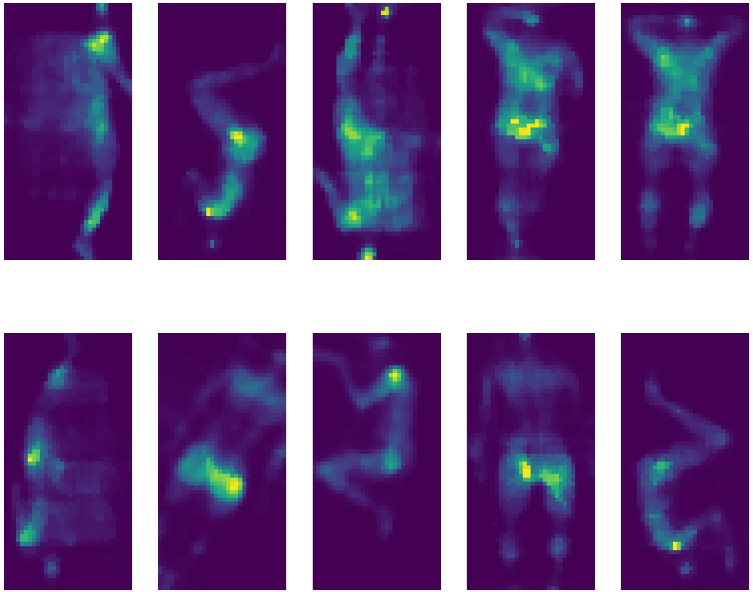
Illustration of some pre-processed images compared with the related raw ones.

Data Augmentation

A more diverse dataset for a more robust model

Augmented data are always used for training → more robust models.

Probability	Process
50%	Rotation by 180°
20%	Rotation by up to ±30°
20%	Horizontal shift by up to ±10%
20%	Vertical shift by up to ±10%



Processing Pipeline

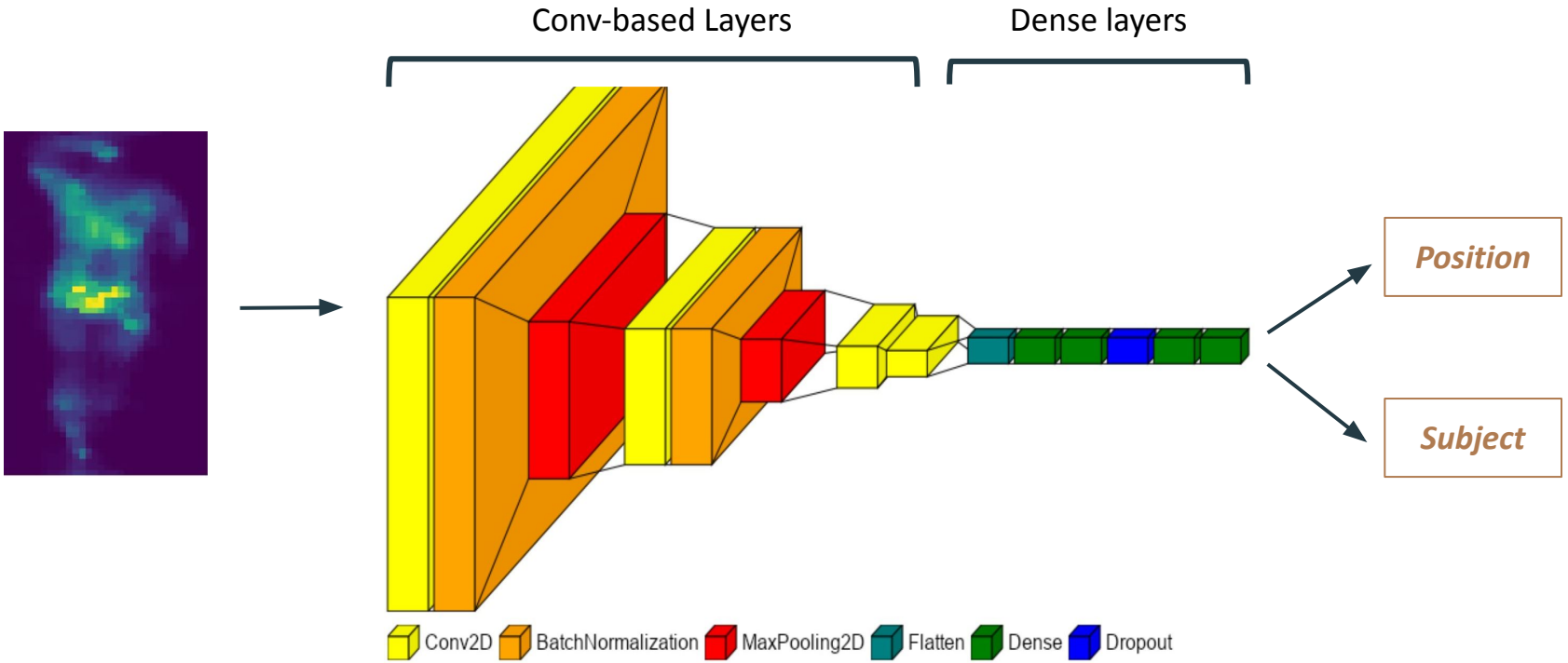
Implemented Architectures:

- Comparison between CNN, CNN+RNN & CNN+LSTM architectures, with around 130’000 parameters each;
- Based on the results of that comparison, a more complex architecture has been implemented from scratch.

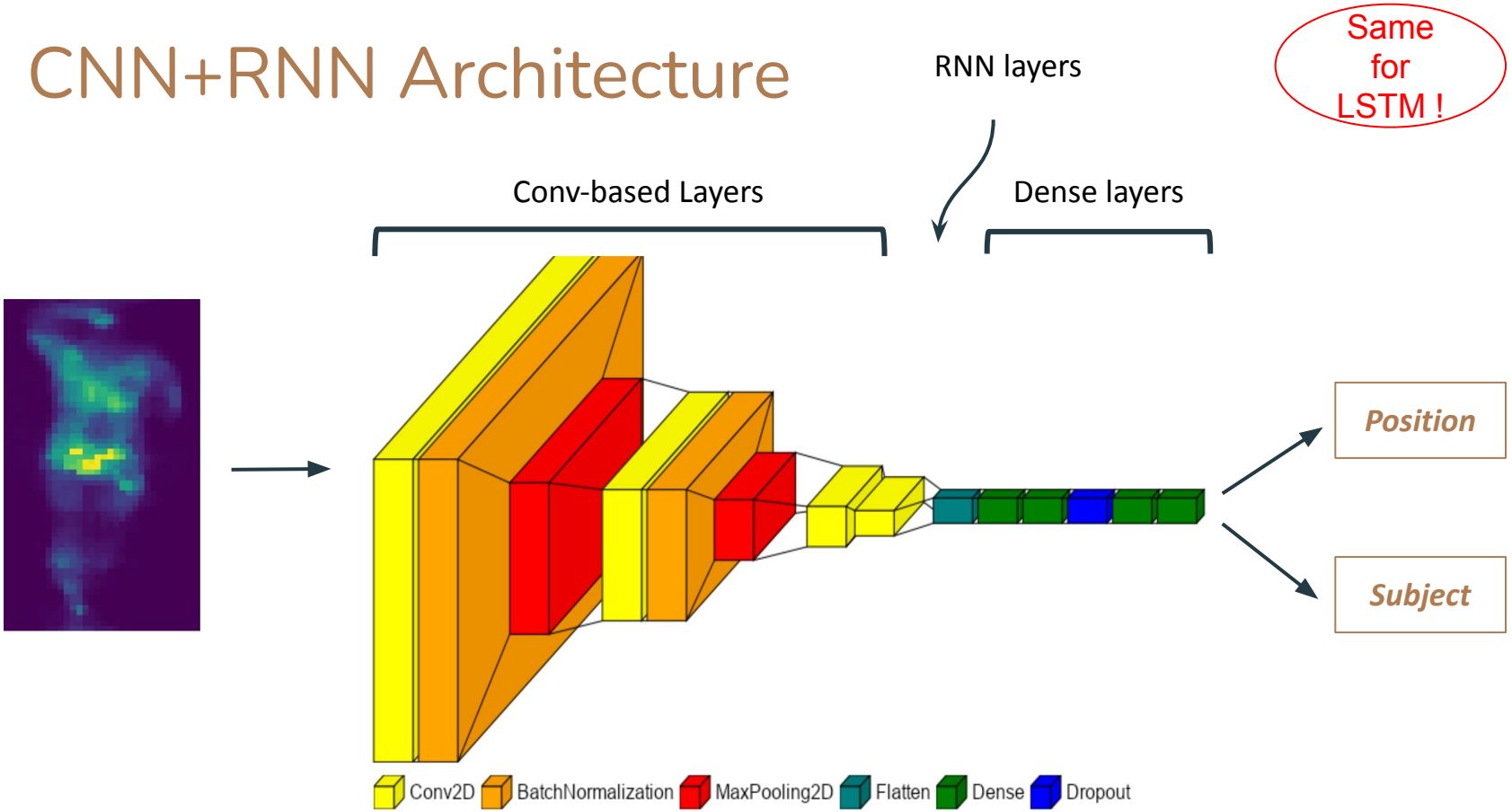
Building Blocks of each architecture:

- 64x32 input images;
- Multitask learning framework to classify subject and posture simultaneously has been used in all the tested models;
- CNN-based feature extraction;
- Always training with augmented data, to reduce overfitting and especially to increase the ability of the models to generalize to more diverse datasets;
- Random Training-Test splitting (the dataset is balanced both in subjects and postures).

CNN Architecture



CNN+RNN Architecture



CNN or CNN+RNN ?

13 SUBJECTS ACCURACY (in %)

Architecture	10-fold
CNN	99.33 ± 2.11
CNN + RNN	98.6 ± 2.0
CNN + LSTM	92.56 ± 9.73

17 IN-BED POSTURES ACCURACY (in %)

Architecture	10-fold	LOSO
CNN	99.67 ± 0.37	80.1 ± 8.7
CNN + RNN	98.79 ± 2.19	74.3 ± 6.9
CNN + LSTM	94.97 ± 8.52	74.5 ± 9.5

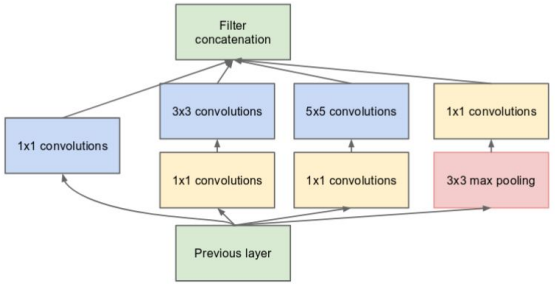
LOSO (Leave-One-Subject-Out)

Training on twelve subjects and test on the remaining one, then reiterate for all the others.

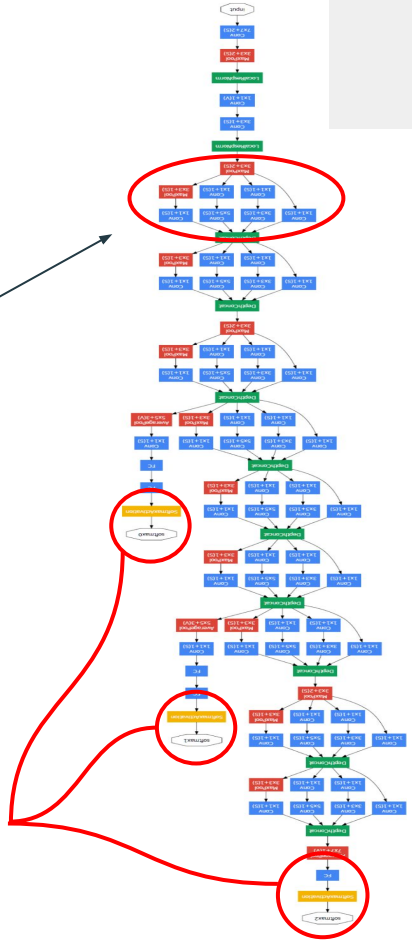
High accuracy with LOSO validation scheme means better classification with new subjects!

GoogleNet

Inception Block



GoogleNet Architecture



Backpropagated singularly !

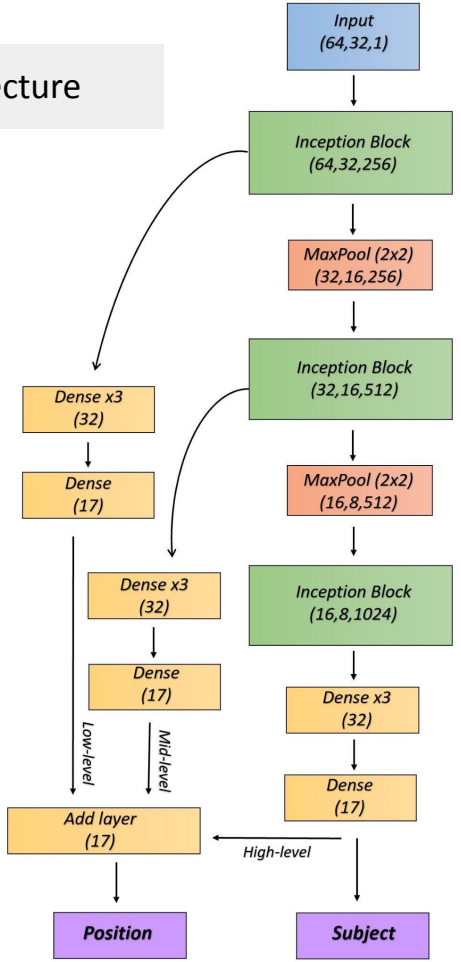
[7] C. Szegedy, W. Liu, Y. Jia, P. Sermanet, S. Reed, D. Anguelov, D. Erhan, V. Vanhoucke, and A. Rabinovich, "Going deeper with convolutions," 2014.

Our Model

- Inspired by **GoogleNet**
- *Add layer* for low-mid-high level features
- *Loss function* for *subject & posture classification*

$$\mathcal{L} = \lambda \mathcal{L}_{user} + (1 - \lambda)\mathcal{L}_{posture}$$

Our Architecture



Results

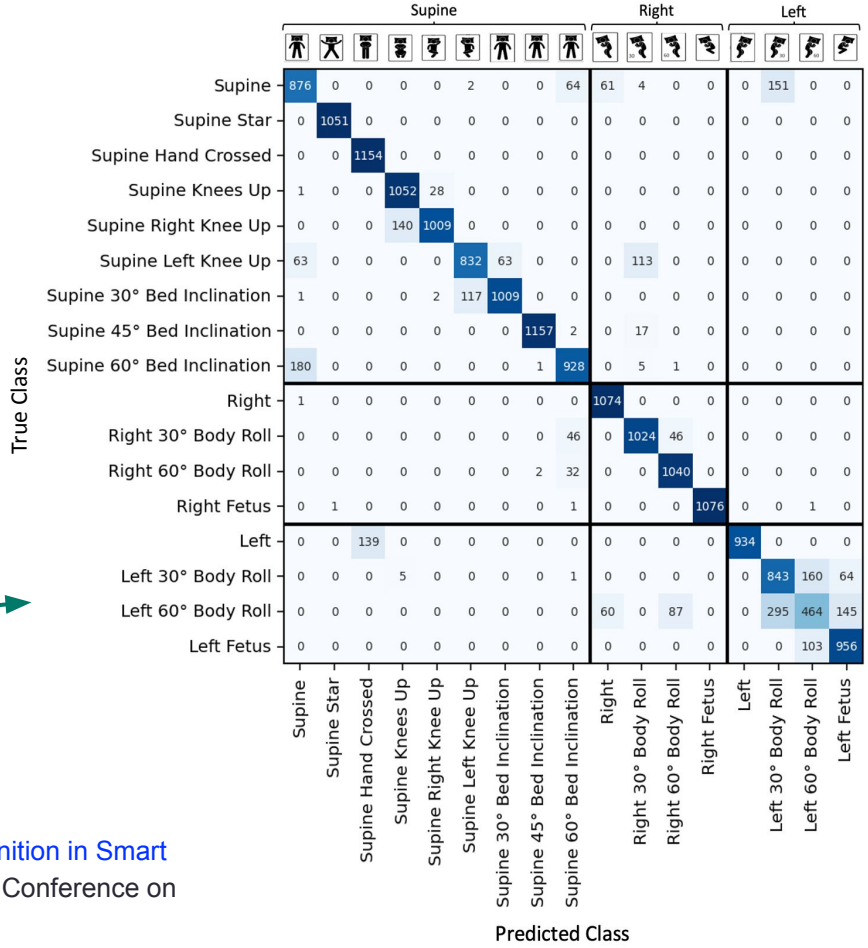
13 SUBJECTS ACCURACY (in %)

Architecture	10-fold	10-fold *(a.t.)*
Our Model	100	98.0
Model [6]	100	89.7

17 IN-BED POSTURES ACCURACY (in %)

Architecture	10-fold *(a.t.)*	LOSO	LOSO *(a.t.)*
Our Model	98.6	87.7	85.4
Model [6]	93.2	87.0	75.6

(a.t.) in column names means that model have been tested on augmented images.
100% posture accuracy was achieved in the 10-fold validation scheme when testing on non-augmented data.



[6]: [Davoodnia19] V. Davoodnia and A. Etemad, Identity and Posture Recognition in Smart Beds with Deep Multitask Learning, in Proceedings of the IEEE International Conference on Systems, Man and Cybernetics (SMC), Bari, Italy, 2019.

Conclusions

Achievements

- Inception modules is all you need!
- Very robust **generalization**!
- Ready to be deployed!

Further Improvements

- Hyperparameter optimization
- *Video-classification* model
- Even deeper architectures (GoogleNet from scratch)

Thanks for the attention!

And now let’s skip to the ***Live Demo***…

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