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GAIT RECOGNITION AND FALL DETECTION WITH INERTIAL SENSORS

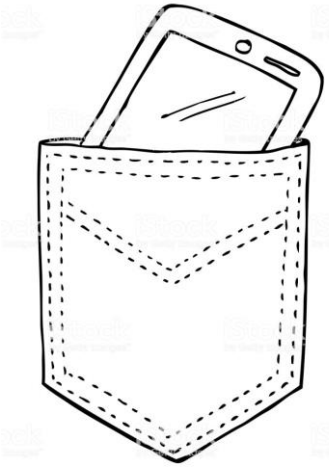
Rubén Delgado-Escaño
Francisco Castro
Manuel J. Marín-Jiménez
Nicolás Guil

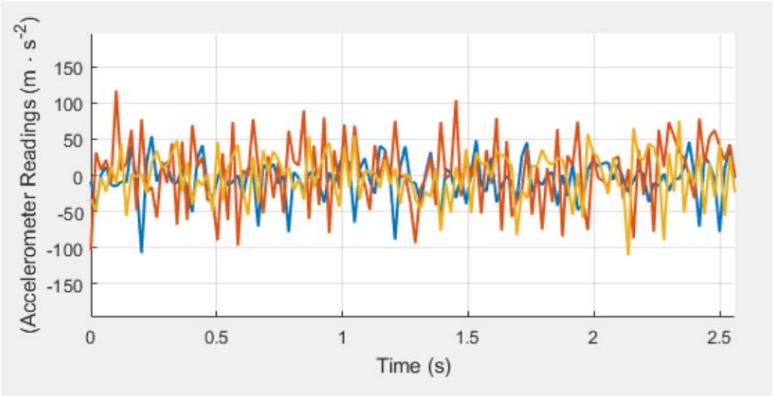
Outline

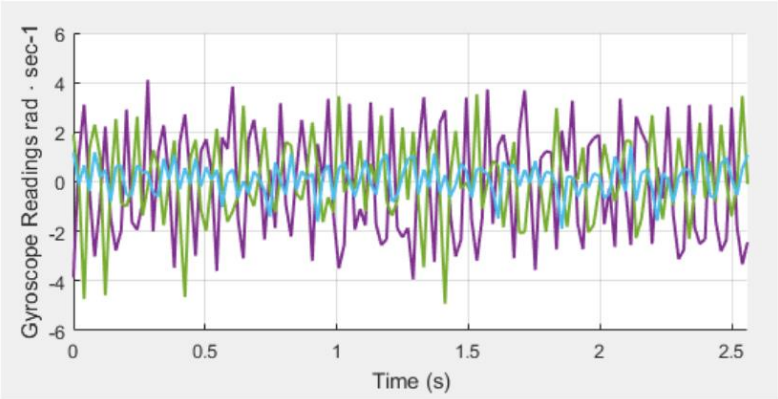
- Inertial sensors
- An End-to-End **Multi-Task** and **Fusion** CNN for Inertial-Based Gait Recognition
- A **Cross-dataset** Deep Learning Classifier for People **Fall Detection** and Identification

Inertial sensors

- Cheap, wearable and pervasive
- We work with two types:
  - Accelerometers
  - Gyroscope
- Samples: sequences of 3-D vectors







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An End-to-End **Multi-Task** and **Fusion** CNN for Inertial-Based Gait Recognition

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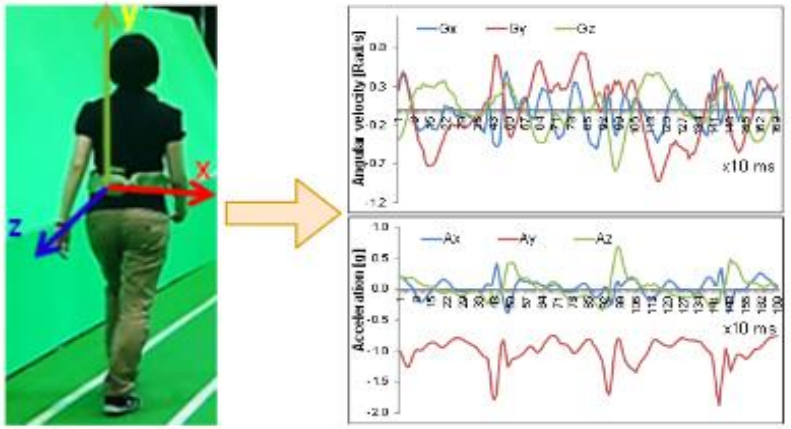
Dataset

- Dataset: OU-ISIR Biometric Database (Osaka University):
  - Subset A:
    - 744 subjects: two sequences at 100 Hz in opposite direction
      - Genre: 389 males and 355 females
      - Age : from 2 to 78 years, discretized in ranges
  - Subset B:
    - 495 subjects
    - Three sensors (left, central, right)



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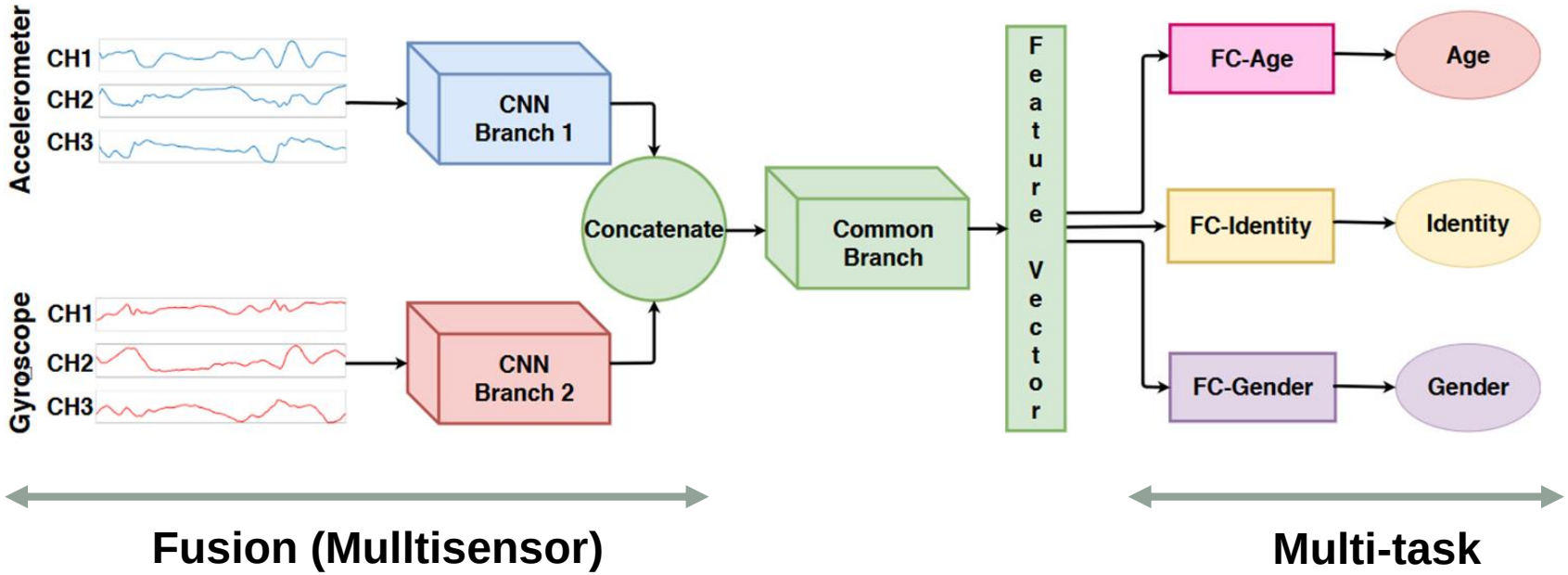
Architecture



- Four convolutional layers + RELU + batch norm. + max pool

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Training

- CNN input: 100 samples subsequence (one second)
- Data augmentation

CNN	*Conv01*	*Conv02*	*Conv03*	*Conv04*	*AvgPool*	*FC*
SingleTask SingleSensor	1 x 10 x 240 P: 1 x 2	1 x 7 x 300 P: 1 x 2	1 x 5 x 360 P: 1 x 2	1 x 3 x 420 P: 1 x 2	1 x 5 Dr: 0.5	C
MultiTask SingleSensor	1 x 10 x 240 P: 1 x 2	1 x 7 x 300 P: 1 x 2	1 x 5 x 360 P: 1 x 2	1 x 3 x 420 P: 1 x 2	1 x 5 Dr: 0.5	$C_{id} + C_{age} + C_{gender}$
SingleTask MultiSensor	Acc: 1 x 10 x 240 P: 1 x 2 Gyr: 1 x 10 x 240 P: 1 x 2	1 x 7 x 300 P: 1 x 2	1 x 5 x 360 P: 1 x 2	1 x 3 x 420 P: 1 x 2	1 x 5 Dr: 0.5	C
MultiTask MultiSensor	Acc: 1 x 10 x 240 P: 1 x 2 Gyr: 1 x 10 x 240 P: 1 x 2	1 x 7 x 300 P: 1 x 2	1 x 5 x 360 P: 1 x 2	1 x 3 x 420 P: 1 x 2	1 x 5 Dr: 0.5	$C_{id} + C_{age} + C_{gender}$

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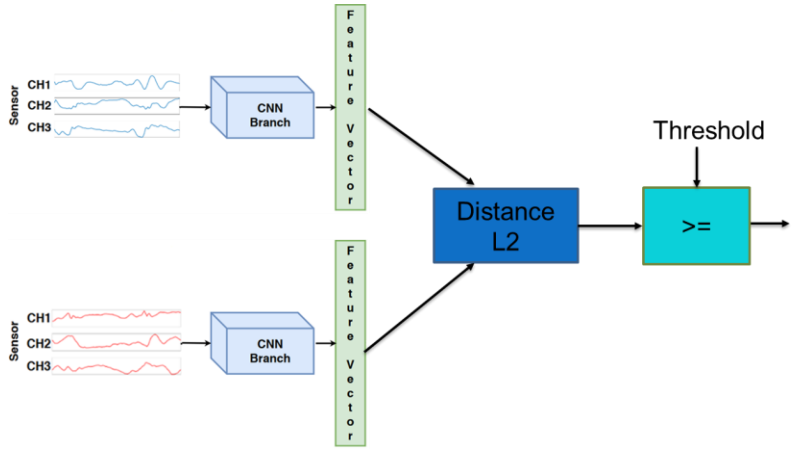
Model comparison results

Gait **recognition** accuracy and F1-score

	Acc				F1-score			
Architecture	*Id*	*Age*	*Gender*	*Avg*	*Id*	*Age*	*Gender*	*Avg*
SingleTask Accelerometer	89.7	91.0	94.8	91.8	87.6	91.3	94.5	91.2
SingleTask Gyroscope	89.1	89.1	94.4	90.9	87.5	89.7	94.4	90.5
MultiTask Accelerometer	90.9	93.3	95.9	93.4	89.1	93.3	95.9	92.8
MultiTask Gyroscope	90.1	90.1	94.8	91.7	88.3	90.5	94.9	91.2
SingleTask Fusion	94.2	95.0	95.6	94.9	93.5	95.0	95.6	94.7
MultiTask Fusion	**94.8**	**96.1**	**97.7**	**96.2**	**93.8**	**96.3**	**97.7**	**95.9**

Gait **authentication** accuracy

Architecture	*EER*	*AUC*
SingleTask Accelerometer	1.47	99.91
SingleTask Gyroscope	2.50	99.80
MultiTask Accelerometer	1.61	99.90
MultiTask Gyroscope	2.85	99.72
SingleTask Fusion	**1.14**	**99.93**
MultiTask Fusion	1.34	99.92



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State-of-art comparison

Gait **recognition** accuracy

CNN	*Id*	*Age*	*Gender*	*Avg*
AE-GDI-CNN [11]	61.0	-	-	-
Muaaz *et al.* [58]	63.5	-	-	-
Ngo *et al.* [21]	70.2	-	-	-
Wei *et al.* [12]	83.8	-	-	-
MultiTask Fusion (Ours)	**94.8**	**96.1**	**97.7**	**96.2**

Gait **authentication** accuracy

Approach	*EER*
Gafurov *et al.* [39]	15.8
Derawi *et al.* [42]	14.3
Rong *et al.* [40]	14.3
Ngo *et al.* [21]	13.5
Inp GDI + i-vector [9]	7.1
NC GDI + i-vector [9]	5.6
SingleTask Fusion (Ours)	**1.1**

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A **Cross-dataset** Deep Learning Classifier for People **Fall Detection** and Identification

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Motivation

- Progressive aging of population
  - Falls are a leading cause of accidents and loss of autonomy among the elderly
- Datasets with a lot of variety among each other

Dataset	*Subjects*	*Sensors*	*Frequency*	*Position*	*Length*	*N-Fold*
DFNAPAS [28]	10	1 acc	50Hz	Pockets	301	10
SisFall [29]	38	2 acc 1 gyr	200Hz	Waist	2k-36k	10
UniMiB-SHAR [30]	30	1 acc	50Hz	Pockets	51	5
ASLH [31]	17	6 acc 6 gyr 6 mag	25Hz	Thigh	210-945	10

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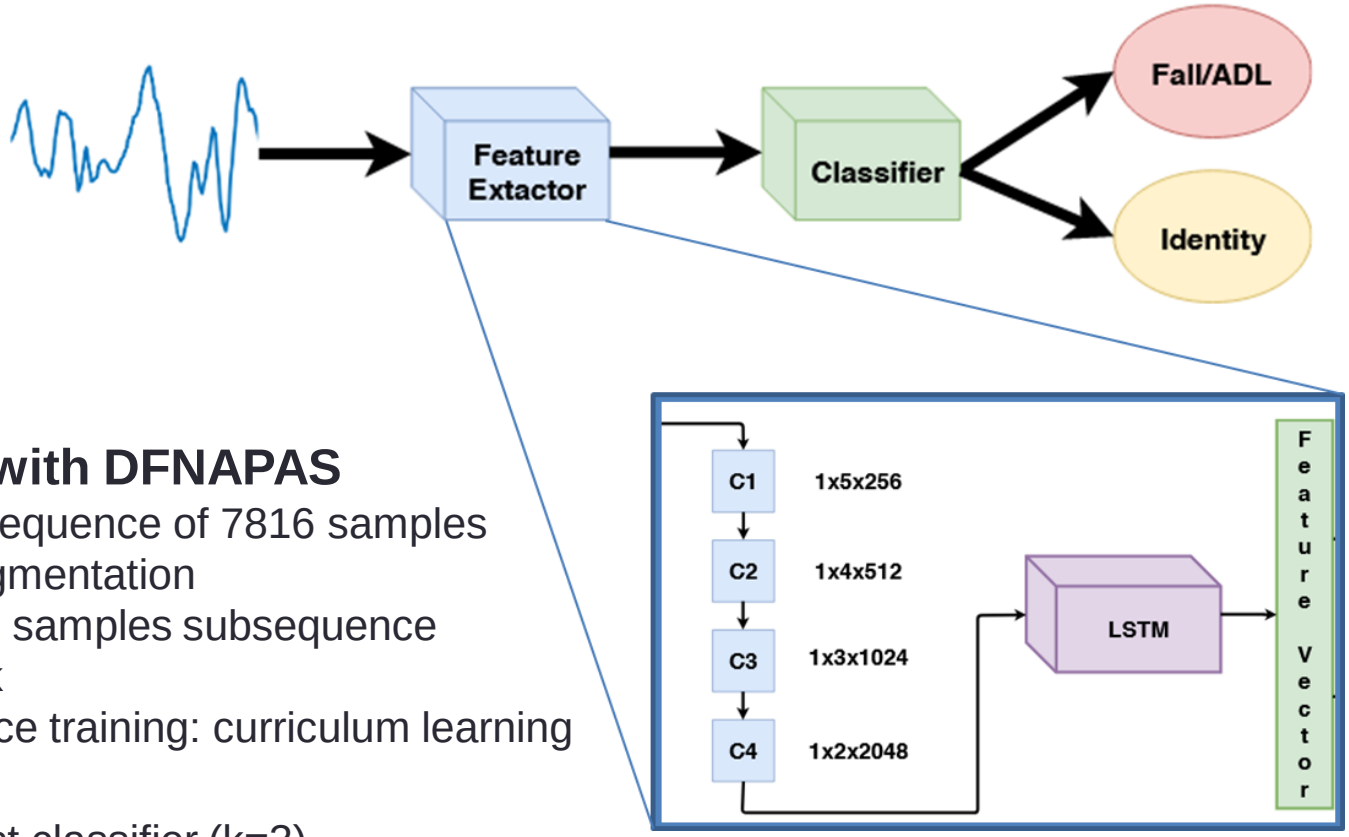
Architecture



- **Training with DFNAPAS**
  - Length sequence of 7816 samples
  - Data augmentation
  - Input: 50 samples subsequence
  - Multitask
  - Unbalance training: curriculum learning
- **Test:**
  - k-Nearest classifier (k=3)

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Experimental results

		Fall Detection				Identity Recognition
Dataset	Method	*Accuracy*	*Sensitivity*	*Specificity*	*MAA*	*Accuracy*
DFNAPAS	Medrano *et al.* [15]	97.70	95.40	92.40	-	-
	Ours	**99.88**	**98.66**	**99.96**	**99.31**	**80.20**
SisFall	Sucerquia *et al.* [16]	96.10	-	-	-	-
	Ours	**99.16**	**99.24**	**99.10**	**99.17**	**74.58**
UniMiB-SHAR	Micucci *et al.* [17]	97.03	-	-	**94.87**	-
	Ours	**97.17**	**89.69**	**99.56**	94.63	**82.00**
ASLH	Ozdemir *et al.* [18]	**99.61**	-	-	-	-
	Ours	96.64	**98.03**	**94.94**	**96.49**	**81.72**

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Thanks!