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Studente: Diego Droghini

Università Politecnica delle Marche
Progetto Eureka

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Ambient Intelligence: Computational Audio Processing For Human Fall Detection

Outline

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Human fall: a real problem for society

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"And why do we fall, Bruce? So we can learn to pick ourselves up" cit. Alfred - Batman Begins

- 62% of injury-related hospitalizations for the people over 65 years are the result of a fall [1]
- main cause of death due to accidents for people over 65 [2]
- can lead to psychophysical repercussions on people [3]

What can be done whit FCS

- Monitoring of the elderly or people who live alone
- Assistance time reduction

Fall Classification System Challenge [4]

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- Try to collect sufficient human fall data: supervised or analytical methods
  - difficulty in retrieving examples that represent human falls
- Deal with no human fall data: Novelty detection approach
  - good description of "normality"

Related Work

- Wearable
  - **Accelerometers**
  - Gyroscopes
- Ambient
  - **Vision System**
  - Audio microphone
  - Radar doppler

Issues

- no standard datasets;
- no standard methodology
- difficult comparison with other methods;
- no audio dataset available
- scarcity of real human falls

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Motivations and Contributions

Analytical methods:

- exploiting some a priori knowledge;
- manual tuning of the hyperparameters;
- applying a threshold on aquired signals or features;

They can hardly perform when the operating conditions and the subjects are variable.

Machine learning methods:

- learns from the data;
- can be eforced by exploiting some a priori knowledge;
- no need of manual tuning of the hyperparameters;

They need more data!

Contributions

- audio based fall detection is a reliable alternative;
- proposal and evaluation of the FD task dedicated FAS sensor;
- proposal of the acoustic A3FALL dataset to the community.

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Floor Acoustic Sensor[1]

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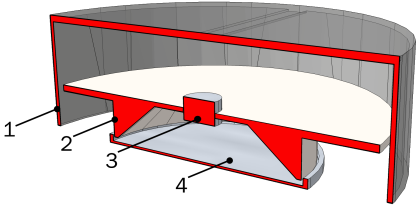
1. The outer container
2. The inner container
3. The microphone slot
4. The membrane touching the floor



Advantage

- Easily integrated into the environment
- More sensitive to signals related to falls

3D printed prototype

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The fall events dataset: A3Fall

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Recording Rooms

- R0 - rectangular room particularly suitable for the propagation of acoustic waves through the floor;
- R1 - university auditorium room in which the flooring is composed of fitted carpet;
- R2 - a recording studio
  - sensors placed in the live room;
  - audio events performed in the control room.

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Recording set-up

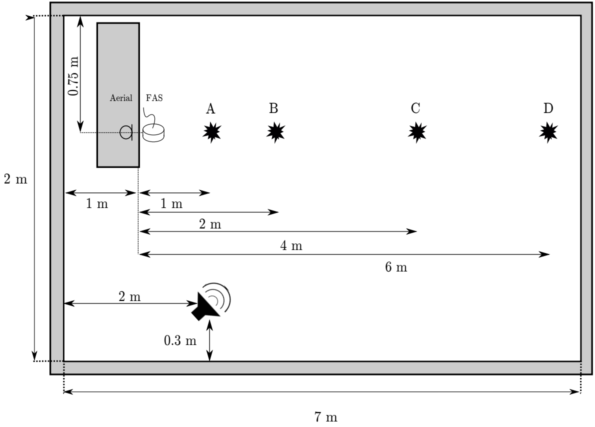
Sampling

- Sample Rate: 44.1 kHz
- Bit-depth: 24 bit

Used sensors:

- Mic. array (3)[1]
- FAS v1[1]
- FAS v2[1]

The recording room

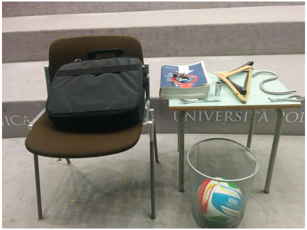


[1]AKG C400 BLT.

[2]RODE Lavalier.

Description

Class	R0	R1	R2
	Nr. of occurrences		
Basket	64	40	40
Fork	64	40	40
Ball	64	40	40
Book	64	40	40
Bag	64	30	40
Chair	96	40	40
Table	0	40	40
Guitar Slide	0	40	40
Nipper	0	40	40
Keys	0	40	40
Hook	0	40	40
Coat Hook	0	40	40
Manikin Doll	44	0	0
Human Fall	0	40	40
	Total length (s)		
Background	2530	9055	5550



Signals analysis

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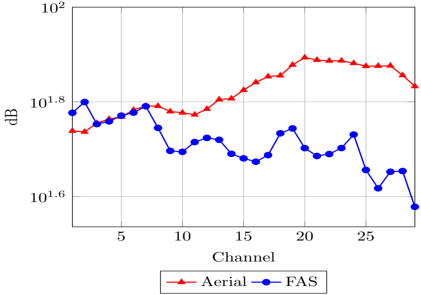
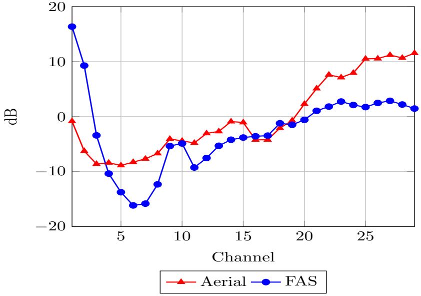
Average value of the mel channels



Average value of the SNR for each mel channel



Remark

- The “valley” in the curves is due to the pitch of the music signal
- The FAS is better at low frequencies

Supervised Approaches: SVM based

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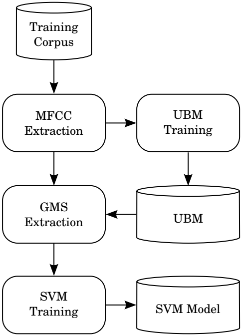
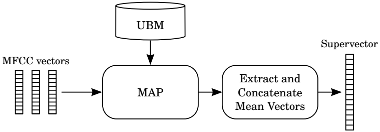
- Completely supervised scenario
- GMM to model a UBM with EM algorithm
- MFCC features to Supervectors (MAP)
- SVM classificator





Scenarios

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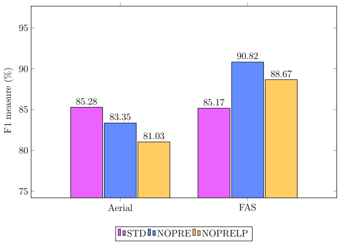
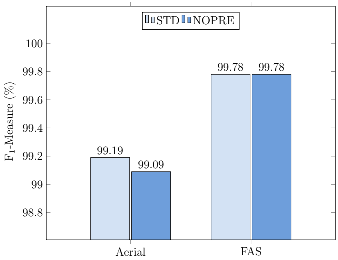
Multi-class

Trained to discriminate the type of the fallen object



Bi-class

Trained to discriminate fall from non-fall



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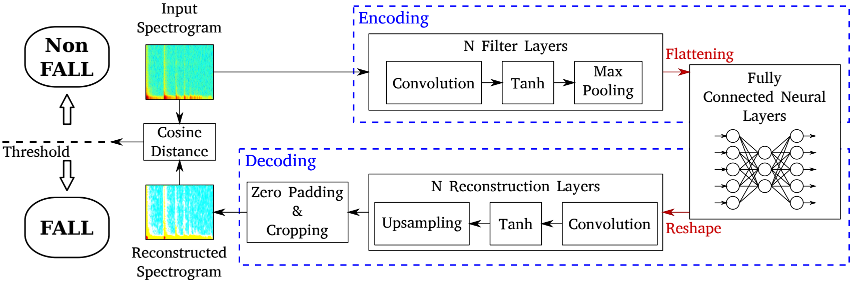
Unsupervised Approach



Results

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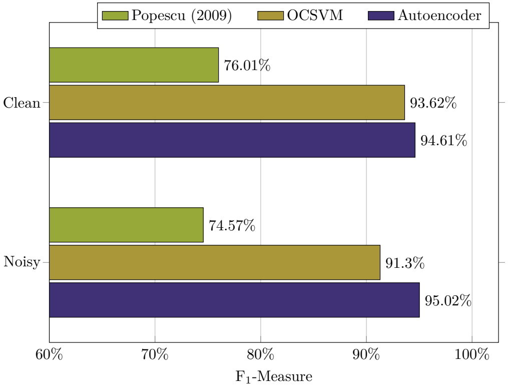
- Trained with background sounds only
- Tested with:
  - background
  - human fall



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OCSVM user-aided

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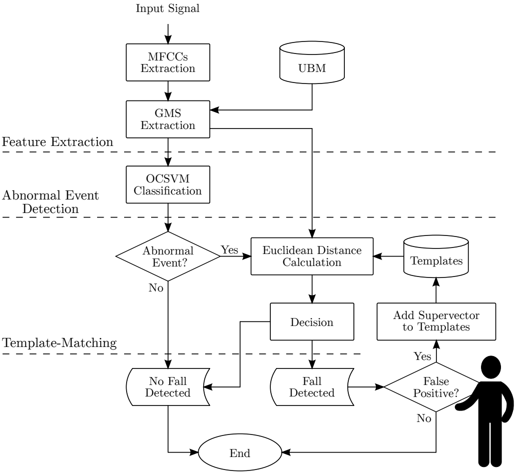
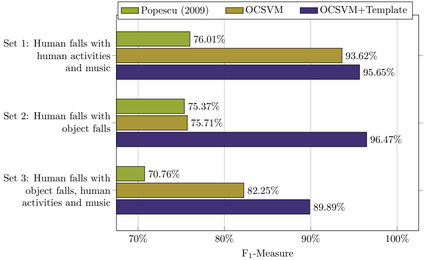
- 1° Stage: OCSVM
  - trained with non-fall event
- 2° Stage: template matching
  - based on Euclidean Distance
- Final decision
  - user-aided: false positive report

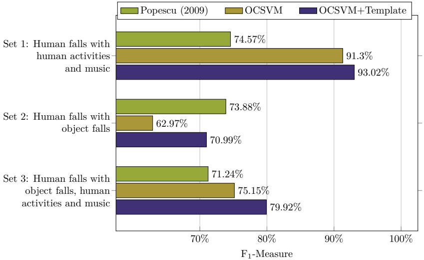


Results

Clean condition



Noisy condition



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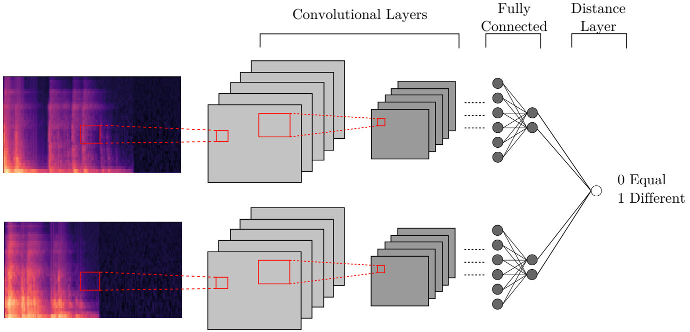
Few-shot Siamese Neural Networks



$$Loss = (1 - Y)\frac{1}{2}(E_w)^2 + (Y)\frac{1}{2}\{(max(0, m - E_w)\}^2$$

Training Phase

Consider X_1, X_2 as a pair of two input samples.

Euclidean Distance

$$E_w = \left\| S_e(X_1) - S_e(X_2) \right\| . \tag{1}$$

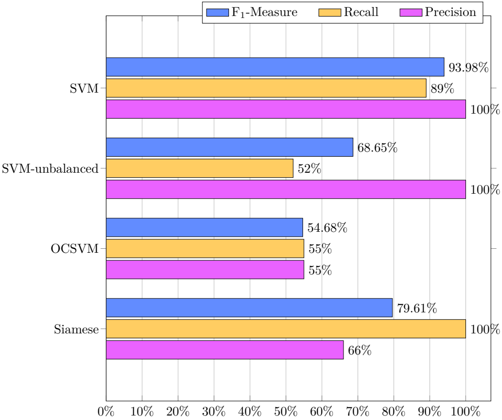
with $S_e(X1)$ and $S_e(X2)$ the mappings performed by the network

The label for training a SNN are built as follows:

- Positive examples labelled as 0: pair of input samples belonging to the same fall event class
- Negative examples labelled as 1: pair of input samples not belonging to the same fall event class

Results

- Data augmentation
- Trained:
  - objects fall
  - 1 human fall
- Tested with:
  - objects fall
  - human fall



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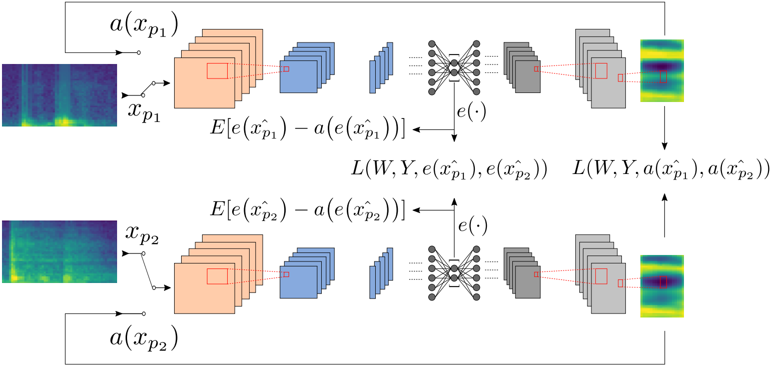
OneShot Siamese Autoencoders



Training procedure

- Contrastive loss of latent spaces
- Contrastive loss of reconstructions
- Recostruction loss (mse) of latent spaces
- To exploit the few human fall samples available a smart selection of the train pairs has been done:
    - Neither the real falls nor the simulated falls were coupled with the falls of the objects
    - Simulated and real falls were coupled together
- induces the network to make a transformation in the latent layer
- simulated human fall can be used as real human fall template in the final classifier
- KNN classifier

Latent space with 2 neurons

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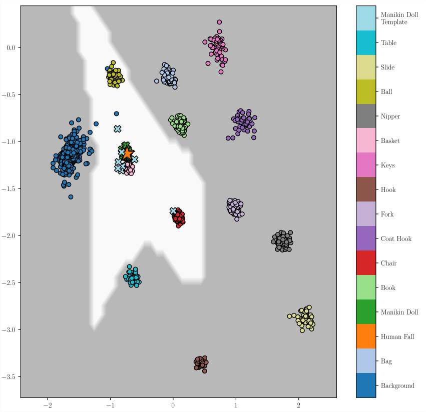
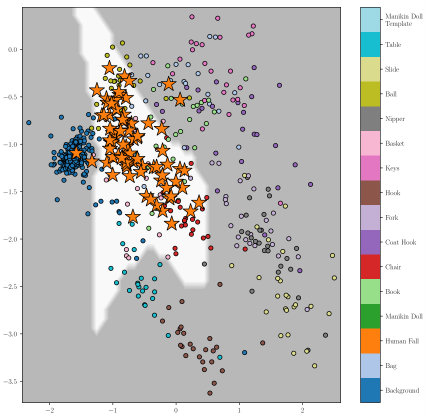
Train set

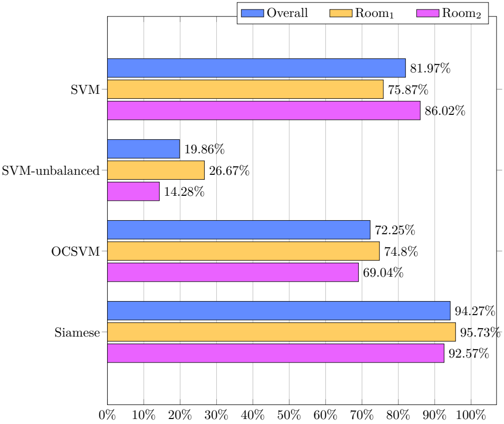


Test set



Results

- Trained (3 room):
  - objects falls
  - backgrounds
  - manikin doll falls
  - 1 human fall per room
- Testset composed of:
  - objects fall
  - human fall
  - backgrounds



Audio Timbre Transfer

Conclusions

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D. Droghini, D. Ferretti, E. Principi, S. Squartini, and F. Piazza,
"A combined one-class svm and template matching approach for user-aided human fall detection by means of floor acoustic features,"
Computational Intelligence and Neuroscience, vol. 2017, 2017,
Article ID 1512670.

Publications List (1)

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International Journal: *[3 articles, 2 first author]*

- [1] Principi, E., Droghini, D., Squartini, S., Olivetti, P., Piazza, F.:,
  "'Acoustic cues from the floor: a new approach for fall classification,"
  Expert Systems with Applications, 2016.

- [2] Droghini, D., Ferretti, D., Principi, E., Squartini, S., Piazza, F.:,
  "A combined one-class svm and template matching approach for user-aided human fall detection by means of floor acoustic features,"
  Computational Intelligence and Neuroscience, 2017.

International Journal (submitted): *[1 article, 1 first author]*

- [1] Droghini, D., Principi, E., Squartini, S., Gabrielli, L., P., Piazza.,
  "Audio Metric Learning by using Siamese Autoencoders for One-Shot Human Fall Detection,"
  IEEE Transactions on Emerging Topics in Computational Intelligence, 2018, submitted.

International Conference: *[14 articles, 5 first author]*

Publications List (2)

- [1] Droghini, D., Principi, E., Squartini, S., Olivetti, P., Piazza., F., "Human fall detection by using an innovative floor acoustic sensor," in *Proc. of WIRN*, Vietri sul Mare, Italy, May, 2016.
- [2] Gabrielli, L., Cella, E., Vesperini, F., Droghini, D., Principi, E., Squartini, S., "Deep Learning for Timbre Modification and Transfer: An Evaluation Study," in *Proc. of AES*, Milan, Italy, May, 2018.
- [3] Droghini, F., Vesperini, F., Principi, E., Squartini, S., Piazza., F., "Few-shot Siamese Neural Networks employing Audio features for Human-Fall Detection", in *Proc. of PRAI*,Kean University, Union, NJ, USA, Aug 2018.
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Others:

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