COMBINING CLASSIFIERS WITH DIFFERENT FOOTSTEP FEATURE SETS AND MULTIPLE SAMPLES FOR PERSON IDENTIFICATION

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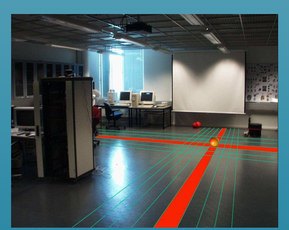
Overview

- **A method for footstep-based person identification on pressure-sensitive floor is presented**
- **Method takes advantages from the combination of multiple classifiers and multiple samples**
- **Over 90% recognition rate of eleven walkers is achieved**

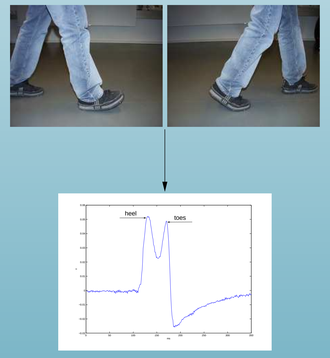
- **Overall aim of this research is to build an intelligent environment: utilizing pressure-sensitive floor to learn and react to behaviour of occupants**
- **Example applications of footstep identification (and tracking):**
  - **Monitoring hazardous situations**
  - **As a part of surveillance system**
  - **Helping child care**

Sensor, Environment and Footstep Patterns

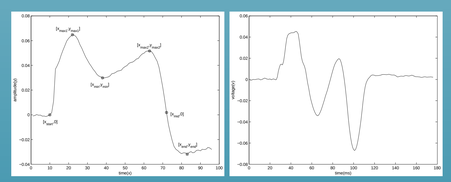
- **Sensor material**
  - ElectroMechanical film (EMFi) material
  - External force makes an impact to its surface: from force to voltage



- **Environment**
  - EMFi material is mounted under the carpet in our research laboratory
  - Consists of 64 long, 30 cm wide sensor stripes,
  - Make up a 30x34 matrix, where the cell size is 30x30 cm



- **Footstep pattern**
  - Consists of two clearly observable local peaks resulting from the heel strike and toe push-off
  - In footstep identification, single footstep patterns of walking person are segmented from the raw signal



- Two different presentation of input signal used: **direct signal** (left) and **derivate of signal** (right)

- **Three different feature sets** calculated from the footstep profile:
  1. **Spatial time-domain feature set (SP)**
     - statistical and spatial features: mean, standard deviation, max of heel strike, max of toe push-off, min between heel and toes, area of amplitude etc.
  2. **Frequency-domain feature set of signal (FR1)**
     - Amplitude spectrum of 64-point FFT + PCA
  3. **Frequency-domain feature set of derivate signal (FR2)**
     - Amplitude spectrum of 64-point FFT + PCA

Multi-classifier Multi-sample Classification Method

- **Two-stage identification method:**
  1. **Combining classifiers with different features sets** (SP, FR1, FR2) for single footstep (i.e. sample)
  2. **Combining multiple consecutive footsteps** (i.e., samples)
- Combination is based on classifiers **conditional posterior probability outputs**

1. **Combining partially independent features sets / classifiers** (product rule)

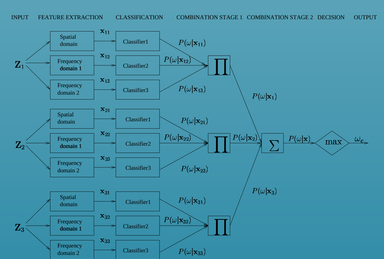
$$\omega_c = \underset{k=1}{\overset{n}{\operatorname{argmax}}} \Big[\prod_{i=1}^{R} P(\omega_k | x_i) \Big].$$

2. **Combining multiple consecutive samples** (sum rule)

$$\omega_c = \underset{k=1}{\overset{n}{\operatorname{argmax}}} \Big[\sum_{i=1}^{S} P(\omega_k | x_i) \Big].$$

3. **Multi-classifier multi-sample method** (product-sum rule)

$$\omega_c = \underset{k=1}{\overset{n}{\operatorname{argmax}}} \Big\{ \sum_{j=1}^{S} \Big[\prod_{i=1}^{R} P(\omega_k | x_{ij}) \Big] \Big\}.$$



Pattern Classifiers

- Two different pattern classification methods were tested in these experiments
- **Learning Vector Quantization (LVQ)**
  - Each feature set was modeled using single LVQ codebook
  - Posterior probabilities were estimated using distance between unknown sample and the closest codebook vectors
- **Multi-layer Perceptron (MLP) Neural Network**
  - Each feature set was modeled using network with one hidden layer and sigmoid activation functions
  - MPLs were trained with backpropagation using scaled conjugated gradient optimization method
  - Softmax criterion was used in output layer to approximate posterior probabilities

Experimental Results

- **Dataset**
  - 11 different walkers, wearing their own shoes
  - 40 segmented footsteps from each walker
- **Modeling**
  - 2/3 for training, 1/3 for testing (hold-out method)
  - 10 times randomly chosen data sets

Feature Set	LVQ (%)	MLP (%)
SP	67.7 (4.9)	72.6 (3.4)
FR1	48.5 (3.7)	55.8 (4.8)
FR2	55.6 (6.2)	61.6 (4.6)
product	74.8 (8.8)	79.2 (7.5)

- Identification accuracies of different features sets (SP, FR1, FR2)
- Combination of all feature sets (product rule)

No. samples	1	2	3	4	5	6	7	8	9
LVQ (%)	74.8 (8.8)	86.1 (5.8)	91.2 (6.1)	93.6 (3.9)	94.6 (4.7)	95.0 (4.5)	95.5 (4.3)	97.3 (4.4)	97.3 (4.3)
MLP (%)	79.2 (7.5)	89.0 (4.4)	92.4 (4.6)	92.4 (6.3)	95.0 (4.5)	95.0 (5.0)	95.9 (5.0)	96.8 (6.1)	98.2 (3.8)

- The identification accuracies using multi-classifier multi-sample method (product-sum rule)
- Results are shown using different number of consecutive samples

Summary

- **Person identification system based on walker's footstep profiles is introduced**
- **Combination of classifiers trained with different feature presentations and fusing consecutive samples are found to be very useful**
- **Results are promising: e.g., using multiple classifiers with 3 consecutive samples 92% recognition rate is achieved**

More info: http://www.ee.oulu.fi/research/isg/