FOOTSTEP IDENTIFICATION FROM PRESSURE SIGNALS USING HIDDEN MARKOV MODELS

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Outline

- Introduction
- Emfi Material
- Hidden Markov Models Classification
- Data
- Test Results
- Conclusions
Introduction

- **What we have done?**
  - Initial experiments on recognizing walkers from the measurements achieved with a pressure sensitive floor
    - A 100 square meter pressure sensitive floor used
    - Test classifications included footsteps from three walkers

- **Methods**
  - Discrete Hidden Markov Models (HMM)
    - One HMM per walker created for classification
    - Overall 78% success rate of footstep identification

- **Aim**
  - A part of research on intelligent environments: to learn and react to behaviour of occupants
    - Monitoring hazardous situations
    - Surveillance systems
    - Helping child care
Emfi Material

• Material
  • ElectroMechanical Film (EMFi)
    • A thin, flexible, lowprice electret material, which consists of cellular, biaxially oriented polypropylene film coated with metal electrodes
    • It is possible to store a large permanent charge in the film by corona method using electric fields
    • An external force affecting on the EMFi's surface causes a change in the films thickness resulting a charge between the conductive metal layers
      – This charge can be detected as a voltage, which describes the changes in the pressure affecting the floor

• Applications
  • Used for many commercial applications
    • Keyboards, microphones in stringed musical instruments and as small and large area sensors
Emfi Material (2)

- **Emfi-floor**
  - In our research laboratory EMFi-material is placed under the normal flooring
  - Consists 30 vertical and 34 horizontal EMFi- sensor stripes, 30 cm wide each
  - Why not Squares?
    - Number of wires
Emfi Material (3)
Emfi Material (4)

- **EMFi-data**
  - Each 64 stripes produces continuous signal
  - Streamed into a PC from where the data can be analysed in order to detect and recognize the pressure events
  - The analogous signal is processed with National Instruments AD-card (PCI-6033E), sampling rate can be chosen between 0.1 - 64 kHz
    - 100 Hz sampling rate is used in these experiments
Hidden Markov Models Classification

- **Hidden Markov Models (HMM)**
  - A natural way for modelling time dependent signals
  - Widely used for speech recognition

- **HMM based classification**
  - Observation sequence generated by a Markov model
    - A Markov model is a finite state machine which changes its state once every time unit
    - Each time $t$ that state $S_j$ is entered, a vector $O_t$ is generated from a certain probability distribution $B$.
    - In practice, only the observation sequence is known and the underlying state sequence is hidden
    - There are different types of HMM’s, discrete Left-Right model was used here

```
S1  a11 a12 a13
    ^   v
      a22

S2  a21 a22 a23
       v
      a33

S3
```

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Hidden Markov Models Classification (2)

- **Footstep classification**
  - Features calculated using overlapping time window
    - Features: mean, standard deviation, maximum, minimum
  - The observation sequence is obtained using Learning Vector Quantization (LVQ) codebook
  - One HMM model for each class (person), prototype model trained with example steps using Baum-Welch estimation
  - Test footsteps are classified choosing the maximum likelihood for each model

![Graph](image.png)
Hidden Markov Models Classification (3)

- HMMs for walker identification

(1) Training

1. Person 1
2. Person 2
3. Person 3

Estimate Models

\[ M_1 \quad M_2 \quad M_3 \]

(2) Identification

Unknown \( O = \)

Choose Maximum

\[ P(O|M_1) \quad P(O|M_2) \quad P(O|M_3) \]
Data

• **Collecting data**
  - Footsteps from three persons, walking alone and casually on the pressure sensitive floor for 30 seconds
    - Data recorded from all the 64 channels
    - Testees weighted 66 kg ± 2, wore their own shoes

• **Pre-processing data**
  - Finding “good-quality” steps from noisy data
    - A raw segmentation made with hybrid-median filters
    - The best footsteps were selected manually
Data (2)

- **Raw data**
Data (3)

- Extracted footsteps
Test Results

• The best initial results
  ▪ 4 state HMM’s
  ▪ Window width: 15 ms, overlapping: 5 ms
  ▪ Features: mean, standard deviation, maximum, minimum
    • normalized between 0 and 1
  ▪ LVQ-codebook size: 256

• The confusion matrix for three persons’ footsteps

<table>
<thead>
<tr>
<th></th>
<th>Person1</th>
<th>Person2</th>
<th>Person3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Person1</td>
<td>72.2</td>
<td>27.8</td>
<td>0</td>
</tr>
<tr>
<td>Person2</td>
<td>36.84</td>
<td>63.16</td>
<td>0</td>
</tr>
<tr>
<td>Person3</td>
<td>0</td>
<td>4.8</td>
<td>95.2</td>
</tr>
</tbody>
</table>
Conclusions

- Initial experiments on identifying persons based on their footsteps were reported
- Basic tools for using the EMFi-floor are developed
- Identification of three persons footsteps is not adequate to enable the generalization of the results for larger population
- Future plans
  - Collecting data from larger population
  - Testing different kind of features
  - Implementing completely different methods