Combined analysis of hand and gait motor function in Parkinson’s disease

Motivation
Motor symptoms are the prerequisite for the clinical diagnosis of Parkinson’s disease. The cardinal symptoms are widely used for disease staging and assessment of progression [1].

Background
Parkinson’s disease – cardinal symptoms
- Bradykinesia – slowing of motor activities
- Rigidity – stiffness and increased muscle tone
- Tremor – trembling of extremities
- Postural instability – impaired balance

Clinical rating of motor symptoms
- UPDRS – Part III
  (Unified Parkinson’s disease rating scale)

Drawback
Rater dependent, thus subjective!

Goal
Objective, automated and mobile diagnostic tool for movement disorders

Sensor setup

Sensor platform
SHIMMER wireless sensor platform
- Embedded processor running TinyOS
- 5D card, Bluetooth and IEEE 802.15.4
- Biosensors:
  o 3D accelerometer
  o 3D gyroscope

BISP – Biometric Smart Pen
- Multisensoric pen system
- HID-USB connection
- Biosensors:
  o 3D accelerometer

Data collection
Standardized gait tests
- 10-meter walk
- Walk on spot
- Heel-toe tapping
- Circling foot movement

Standardized hand motor tests
- Drawing circles
- Tracing pre-printed spirals / meanders
- Pronation / supination movement
- Finger tapping

Experiments and classification results
Extracted and selected features were used for different two-class-classification tasks using a leave-one-subject-out-cross-validation.

Evaluated classifiers were Support Vector Machine (SVM), Linear Discriminant Analysis (LDA) and AdaBoost

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Patient group</th>
<th>Control group</th>
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<tbody>
<tr>
<td>Sex (m/f)</td>
<td>32/10</td>
<td>26/27</td>
</tr>
<tr>
<td>Age (years)</td>
<td>64.3 ± 9.4</td>
<td>61.8 ± 10.2</td>
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<tr>
<td>UPDRS – Part III</td>
<td>18.6 ± 13.1</td>
<td>-</td>
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Table 1: Characteristics of patient and control group

<table>
<thead>
<tr>
<th>Classification task</th>
<th>Sensor</th>
<th>Classifier</th>
<th>BCR</th>
<th>Sens. / Spec.</th>
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<tbody>
<tr>
<td>Patient vs. control</td>
<td>Smart pen</td>
<td>AdaBoost</td>
<td>89</td>
<td>94 / 83</td>
</tr>
<tr>
<td></td>
<td>Sensor shoe</td>
<td>SVM linear</td>
<td>91</td>
<td>88 / 94</td>
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<tr>
<td></td>
<td></td>
<td>Combined</td>
<td>AdaBoost</td>
<td>97</td>
</tr>
</tbody>
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| Patient vs. control (validation group) | Smart pen | SVM linear | 85 | 87 / 83 |
| | Sensor shoe | AdaBoost | 81 | 85 / 76 |

Table 2: Classification results for different classification experiments. BCR, balanced classification rate; Sens.: sensitivity; Spec.: specificity, all values are given in percent

Figure 1: Typical posture and symptoms of a PD patient

Figure 2: SHIMMER wireless sensor platform

Figure 3: Biometric Smart Pen

Figure 4: Patient performing tests: circling foot movement (left); 10-meter walk (right)

Figure 5: Test sheet for standardized hand motor tests

Figure 6: Sensor setup for data capturing: Sport shoe with attached SHIMMER sensor unit (left), patient during hand motor skill tests (right)

Figure 7: Signal examples from controls and Parkinson patients. Upper plots show a gyroscope signal during circling foot movement. Patient had 17 of 108 points in UPDRS– Part III. Lower plots show signals during drawing circles in the air with the smart pen. Patient had 20 of 108 points in UPDRS – Part III.

Figure 8: Pattern recognition includes feature extraction from biosensor signals followed by feature selection and classification of defined subgroups.

Summary and conclusion
Objective and mobile biosensor based movement analysis enables rater independent classification of motor impairments in Parkinson’s disease (PD). Good correlation with clinical ratings by movement specialists provides the base for automated and individualized analysis throughout the day in the normal environment at home. Thus, it complements clinical diagnosis, and improves therapeutic decisions at all stages of PD.

References

This work was funded by the Bavarian Research Foundation, ELAN (Erlanger Leistungszusammenfassung Anschaffungsförderung und Nachwuchsförderung) and by an unrestricted project grant of ASTRUM IT GmbH. Sport shoes were provided by adidas®. We would like to thank all participants of this study.

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