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Posterior probability profiles for the automated assessment of the recovery of patients with stroke from activity of daily living tasks

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Summary

Objective: Assessing recovery after stroke has been so far a time consuming procedure in which trained clinicians are required. A demand for automated assessment techniques arises due to the increasing number of patients with stroke and the continuous growth of new treatment options. In this study, we investigate the applicability of isometric force and torque measurements in activity of daily living tasks to assess the functional recovery after stroke in an automated way.
Methods and materials: A new hybrid filter-wrapper feature subset technology was developed for a new mechatronic platform with the aim to identify the most important features and sensors that can distinguish normal controls from patients with stroke. We compared 3 different classification algorithms to make the distinction: *k*-nearest neighbors, kernel density estimation and least-squares support vector machines. Based on isometric force and torque measurements obtained from 16 patients with a first-ever ischemic or haemorrhagic stroke within the middle cerebral artery territory, we computed for each subject the probability to belong to the class of normal subjects. These probabilities were computed during a period of 6 months post-stroke to quantify the level of recovery during this period. The posterior probabilities were validated by means of a correlation study with the Lindmark modified Fugl-Meyer assessment.
Results: Patients with stroke and normal controls could be distinguished with an accuracy of 98.25% by means of kernel density estimation. The posterior probability profiles had a correlation of 76.6% and 80.29% with the global score of the Lindmark modified Fugl-Meyer scale and 'part A', the upper extremity subscore, respectively. This degree of correlation was as high as obtained with supervised scoring techniques such as the Barthel index.

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Conclusion: This study shows that the assessment of recovery after stroke can be automated by means of posterior probability profiles due to their high correlation with the Fugl-Meyer assessment. The posterior probability profiles confirm the importance of a recovery within the first weeks after stroke to obtain a higher recovery plateau compared to later changes in recovery.

1. Introduction

1.1. General background on stroke

The World Health Organization (WHO) defines stroke as a syndrome consisting of the rapid onset of a focal cerebral deficit of vascular origin lasting more than 24 h [1]. Stroke, also known as cerebrovascular accident (CVA) or 'brain attack', ranks 3rd among all causes of death behind heart diseases and cancer in the United States [2]. It is expected to become the major cause of death worldwide. Moreover, it is number 1 as a leading cause in long-term disability in the United States [3]. Patients with stroke suffer from disabilities ranging from hemiparesis, gait disturbance, incontinence, cognitive disturbance, vision disturbance, dependency in activities of daily living tasks, aphasia, numbness to depressive symptoms [4]. The symptoms are largely dependent on which part of the brain is affected by the stroke and the size of the affected part. In [5] the degree of white matter lesions (WML) was found to be correlated with global cognitive function, executive dysfunction, impaired memory functions and impaired activity of daily living.

Several factors have been shown to contribute to an increased risk for stroke: atrial fibrillation, cigarette smoking, diabetes, high blood pressure, hypercholesterolemia and obesity among others [2].

It is estimated that the direct and indirect cost related to stroke is $65.5 billion in 2008 in the United States [2]. Largest contributors in the acute care costs are [6]: room charges (50%), medical management (21%) and diagnostic costs (19%). For details on stroke incidence, stroke symptoms, stroke risk factors and stroke costs the reader is referred to [2] and the references therein.

1.2. Research motivation

For Europe it is expected that the proportion of the population aged $\geq$65, in which most stroke events occur, will increase from 20% in 2000 to 35% in 2050 and the median population age will rise from 37.7 years in 2000 to 47.7 years in 2050. Moreover the global number of people living in Europe will decrease from 728 million in 2000 to 705 million in 2050 resulting in fewer young people taking care of the increasing proportion of elderly people [7]. Tempering the costs of stroke care will be a tremendous challenge for future health care systems [8]. Nowadays a large number of patients with stroke benefits from comprehensive inpatient rehabilitation and to, support and quantify functional recovery robots and mechatronics technology were successfully introduced [9,10]. It is important that rehabilitation specialists have objective tools to assess recovery, the ability to recover and the effect of therapies on the recovery process. This will help in reducing the stay of patients in hospitals and hence moderate the costs. Current techniques require a clinician to score the performance of patients in some tasks on specific scales: disability scales, e.g. Barthel index (BI), functional independence measure (FIM), global deficit rating scales, e.g. the National Institutes of Health Stroke Scale (NIHSS) [11,12]. These scales require trained therapists to score patients with stroke according to preset rules, which can be very time consuming [11]. A demand for automated assessment techniques arises due to the increasing number of patients and the continuous growth of new treatment options [11].

Artificial intelligence (AI) techniques may be good candidates to assist clinical experts in decision making in stroke rehabilitation. They have been proven useful as a decision tool for thrombolysis [13] after stroke. However, if the patient cannot be treated within 3 h [14] after the onset of the first symptoms of the stroke with thrombolysis damage to the brain is likely to occur and one has to consider rehabilitation, e.g. by means of physical therapy [15—18].

The following research uses artificial intelligence techniques to automate the assessment of functional recovery after stroke by processing force and torque patterns exerted by patients during the performance of particular activity of daily living tasks.

For this purpose a mechatronic platform [19,20] (Section 2.2) and feature subset selection technology (Section 2.4.2) were developed and the Bayesian inference mechanism (Section 2.4.1) was used. These technologies together form the artificial intelligence system.