Assessing the success of stroke rehabilitation with wearable sensors

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Introduction

In common practice a therapist needs to personally consult a stroke patient in a face-to-face intervention for determining the individual progress in the rehabilitation process after a stroke to validate the level of recovery of physical and cognitive impairments within fixed time frames. This is obviously hard or impossible to achieve in a tele-medical rehabilitation setting due to the absence of the therapist. The StrokeBack project is developing an automated remote rehabilitation system for home settings that empowers the stroke patients to perform rehabilitation in their own home without presence of therapists, while still remaining under medical and therapy control. A personal health record coordinates the individual therapy and stores results respectively.

One of the most important rehabilitation goals for therapists and patients is to regain independence from care givers and improve their quality of daily life. Therefore, the impact of training should particularly be monitored and assessed in normal life situations, where no dedicated rehab training takes place. Therefore, we have developed a wearable sensing system that monitors upper limb activities to classify activities of daily living to complement the StrokeBack approach. This easy to use sensing system autonomously collects and classifies about usage of affected upper body parts.

Methods

The basic idea is to use sensing data from state of the art inertial sensors and gyroscopes worn on the body of the patient in a most comfortable way. Obviously, the two key challenges are how to analyse sensor data correctly in software and the development of a sensing hardware platform reliable and stable enough to be used in daily life of the patient. We will here mainly refer to the achievements of the hardware platform. Needless to say that involved therapists and patients have specified several inherent pre-conditions for development, whereof the most important one is allowing a Plug and Play use for patients, since we are targeting on (often elderly) patients with physical impairments. This requires the sensing device(s) to come along without any cables or stackable connectors and to be freely wearable during the whole day. On top of this, a compact and very flat design as well as water resistance is demanded.

Since commercially available sensing platforms lack of at least one required feature, mostly the sensor size or cumbersome connectors, we have developed the wearable sensing platform GHOST, which is depicted Figure 1. In full package, the GHOST system is of matchbox size only, including the sensing and processing devices, a Bluetooth low energy module with integrated antenna for wireless data transfer, a lithium battery and Qi-compliant wireless power supply. In addition, the currently assembled second version will feature a novel security chip that will efficiently encrypt all data using a highly-secure Elliptic Curve Cryptography (ECC).

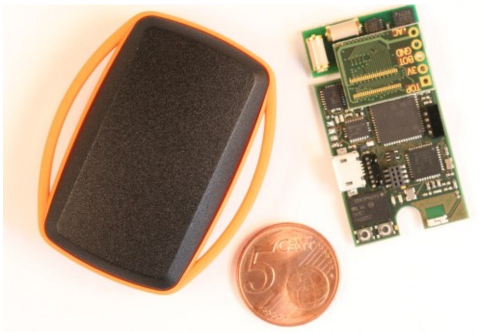

Figure 1 – GHOST sensor platform

The use case scenario for patients is extremely user-friendly. The system is worn on the wrist of the affected arm like a watch. There are only two actions per day required by the patient, i.e. the patient has to take the sensor from the charging station and put it on the wrist in the morning, and merely put it back to the charging station in the evening. The sensor will automatically collect necessary data during the day and transfer it into a personal health record over night while charging.

Results

For the beginning, we target on 3 fundamental movements, i.e. reach and retrieve object, lift cup to mouth and return to table, and swing arm in horizontal plane. We have initially started with using 3 sensors for one arm, one attached to the wrist, one above the elbow and the third one in front of the chest. Using this comprehensive setting, we have been able

to analyse arm movement for calculating angles reached at elbow and shoulder to estimate efficiency of elbow extension and flexion. As a result, all movements can be detection with at least 75 % accuracy.
However, to the sake of simplicity we have shown that reduction to only one sensor attached to the wrist is possible, while achieving up to 88 % accuracy at healthy persons and in between 50 and 85 % accuracy at stroke survivors.

Conclusion

We have developed a smart, wearable sensor platform of matchbox size that allows detection of daily living activities of people under rehabilitation by just being worn on the wrist during the day. This platform generates daily statistics of upper limb usage for therapists, which in turn enables to quantify efficiency of therapy outcome, quality of movement in terms of speed and angles, as well as comparison of affected vs. unaffected body parts if worn on both wrists.