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Fig1. Accelerometer-based classification system for knee arthropathy (source: www.ainsworthinstitute.com/genicular-neurotomy, 2015).

KneeGraphy

CLASSIFICATION OF KNEE ARTHROPATHY WITH ACCELEROMETER-BASED VIBROARTHROGRAPHY

The project aim is to identify early osteoarthritis among the population, recurring only to the use of a miniature accelerometer. For this purpose, machine learning techniques were used to create a system that is able to differentiate signals according to the pathology's presence or absence.

Motivation

The knee joint is one of the most affected anatomical sites in the human body. Besides the obvious traumatic causes, aging process also may greatly influence our current knee joint status.

The knee joint plays a crucial role in the good functioning of the human musculoskeletal system and its compromising may lead to impaired movement, joint pain and tenderness, gait abnormalities and even work disability, depending on the severity of the condition.

The most common disease affecting the knee is osteoarthritis (OA). OA is the most common form of arthritis, involving inflammation and major structural changes of the joint. This condition has a considerable impact on ability to perform daily living tasks such as walking, getting up and down, standing and carrying heavy things. Risk of falling, which has a considerable impact among elderly adults, was also proved to increase with the presence of this kind of knee pathology.

OA may affect people of all ages being predominant among elderly adults (mostly above 50 years old).
Word Health Organization (WHO) considered OA to be ranked as the 11th highest contributor to the global disability ranking.

Moreover, with the aging of the population and with the increasing worldwide rate of obesity and

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External Sensor

- Only the accelerometer was used
- 333 Hz as sampling frequency
- Bluetooth connection for data transfer
- Smartphone (Google Nexus 5) Secure Digital (SD) card for data storage

Dataset

During this preliminary tests some limitations were found, namely:

- Inconsistent leg swing velocity across trials and subjects
- Diagnostic uncertainty of some volunteers
- Diminished angular amplitude of the movement of some subjects
- Sensor's reduced sampling frequency

These limitations are expected to be overcome for the final data collection which is already taking place.

Future Work

- Increase sensor's sampling frequency
- Increase dataset size
- Assure medical accredited background of all subjects
- Keep the leg swinging velocity constant across all trials and subjects
- Use a stethoscope in combination with the accelerometer
- Detect several different sub-pathologies
- Creation of a portable version of the classification system

Fig2. Overall system pipeline.

sedentarism, it will become one of the biggest burdens for health systems across the world.

System Architecture

A preliminary dataset with elderly volunteers (77.5 ± 6.43 years) was collected, recurring to a knee extension/flexion protocol and a miniature accelerometer (Fig3). The protocol consisted in swinging each leg four times, starting from the initial position, with the knee bended at 90°, going to full leg extension (0°) and back to initial position. A time-frequency analysis approach based on wavelet transform (wavelet packet decomposition tree) using the Daubechies 2 (db2) wavelet with 3 levels of decomposition was used to extract signal's features in order to discriminate pathological from healthy knees according to the Vibroarthrography (VAG) signal's time varying changes (Fig2).

Results

The collected dataset was obtained recurring to 8 subjects that displayed the condition and 5 healthy subjects, resulting in 200 pathological and 120 healthy dataset instances, respectively, with a total of 320 instances with 4.832 features. The mentioned dataset was pre-processed using Python and RapidMinner for feature selection. After normalization and application of forward feature selection method, 8 features were chosen to characterize the entire dataset. Selected features were based upon the variance, entropy, kurtosis, skewness, standard-deviation and wavelet's squared coefficients punctual variation across each time slice and correspondent frequency interval and used to train a decision tree classifier which produced a global classification accuracy, sensitivity and specificity of 87.5%, 86.6% and 88.3%, respectively.

Conclusions

A time-frequency based analysis allowed an accurate differentiation between affected and healthy knees due to VAG inherent time varying changes. This approach accounted more for the signal's punctual irregularities and frequency spreadability over the time-frequency domain when comparing a healthy to a pathological knee producing good results.

Fig3. Illustrative image of sensor positioning for knee joint assessment.

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