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学位論文題名	Methodologies Based on Vibroarthrographic Signals for Knee Disorders Diagnosis （関節音に基づいた膝関節症診断の方法論）
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【論文の内容の要旨】

Knee-related diseases have become the largest cause of disability globally, and one of the most dangerous is osteoarthritis (OA) of the knee. OA is now commonly known as a process of cartilage degeneration, which is painless in the early stages of OA. However, once in the end stages of OA, the knee deteriorates rapidly, and mobility is lost. Knee OA occurs in the elderly. About 30% of people over the age of 65 suffer from knee OA, and its possibility increases with age. The most frightening thing is that there is no countermeasure in the end stage of OA, and at best, the patient can only barely walk with an artificial joint replacement. Therefore, a diagnostic technique in the early stages of OA is urgently needed. The ultimate goal of this dissertation is to use a Vibroarthrographic (VAG) Signals technique for the early diagnosis of knee OA. VAG technology differs from traditional medical imaging because it is radiation-free, non-invasive, and inexpensive. Because it does not require a medical professional to operate, it can enter the medical checkup center to serve people in the early stages of knee OA but fail to perceive it. I believe this dissertation can reduce the number of people who fall into disability and poverty due to knee disorders.

Chapter 1 is introductory, and the chapter is subdivided into three parts. Part 1 describes the most critical joints in the human body, the knee, anatomy, and clinical medical science. Moreover, the reasons and benefits of choosing the knee joint as the main object of study are described. Part 2 focuses on the history of VAG signals and reviews its recent research results in medical engineering. Part 3 describes the purpose of the study, the position in comparison with previous studies, and the structure of the dissertation.

Chapter 2 is also subdivided into two parts. Part 1 mainly describes several methods of VAG signal collection. Passive VAG signals are sounded or vibrated by the movement of joints, and three collection means microphone, an inertial sensor, and piezo sensor. Part 2 introduces an original VAG signal collection system composed of a sampling circuit consisting of piezo sensors and inertial sensors and specially designed software. The device's main characteristic is the collection of both VAG signals from the right and left knees and joint flexion and extension angular signals based on required movements.

Chapter 3 focuses on differentiating A patient from a healthy one by the VAG signals collected by inertial sensors. For this purpose, a combined empirical mode decomposition and wavelet analysis VAG signal analysis method was proposed. This technique performs with excellent accuracy in classifying normal and abnormal VAG signals but performs slightly less well in classifying some minor knee disorders.

Chapter 4 presents a method that can excel in the performance of minor knee disorders. In this chapter, an aging and healthy knee is considered a minor disorder knee, and a young and healthy knee is deemed to be healthy. Therefore, an ensemble empirical mode decomposition combined with a short-time Fourier transform approach overcomes this challenge in this chapter. It cannot be said which of these two methods is superior, but they perform differently for various categories of VAG data.

Chapter 5 describes the pre-processing process of the signal in two parts. Part 1 reviews the pre-processing of the VAG signal, mainly including: changing the length of the VAG signal; removing the baseline drift; removing outliers; filling in missing values; and other pre-processing. Part 2 proposes a noise reduction method for VAG signals based on the ant colony algorithm and dynamic filter parameters. The proposed method works for signals with clear peaks and non-stationary signals with less clear peaks. In addition, this chapter also covers post-processing-based techniques to deal with soft-tissue movement artifacts from vibroarthrographic knee-joint signals.

Chapter 6 mainly outlines the feature extraction methods and classification methods for VAG signals and proposes a novel feature extraction method. The novel method particularly proposes a population intelligence algorithm based on the plant root system, which can contain the main information of the VAG signal while having excellent independence. Several classifiers using this feature can improve the classification accuracy between the VAG signal of normal knees and the VAG of abnormal knees.

Chapter 7 focuses on the application of vibration signal on the knee joint model, used to supplement the shortcomings of the VAG signal. The generation principle of the vibration signal is different from that of the VAG signal. The knee joint status is evaluated by comparing the attenuation of the input signal before and after passing through the knee joint without any movement. This is a brave and creative attempt to diagnose joints that are no longer affected by the noise of movement. However, since the input signal is an impact signal, this study is only at the knee model stage for now and is considered for future extension to the clinic.

Conclusions are drawn in Chapter 8. In this chapter, not only the hypothesis proposed at the very beginning of this study is reviewed, the experiments. The results and discussion are again extended further. All the work in this dissertation is summarized and also gives an insightful and precise outlook on the future of VAG signals.