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Adaptive myoelectric control applied to video game

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ABSTRACT

This paper proposes adaptive schemes to cope with time-related changes in muscle activities during playing video game. A myoelectric control with the core of support vector machine is applied to manipulate a car in a computer-based video game. The proposed adaptive schemes model fatigue-based changes in myoelectric signals and modify the classification criteria to keep stable performance in long-term operations. Both unsupervised and supervised methods were applied to detect time-related steady state deviations in myoelectric signal patterns. Both methods improve the performance of myoelectric control and keep it stable in long-term applications.

1. Introduction

Although myoelectric signal (MES) has a high potential to be a novel user interface in the game industry, it lacks required reliability and robustness for long-term operations [1]. There are many commercial devices and numerous literature [2,3] supporting directly or indirectly the idea of using myoelectric based control panels for video games, but few researches have been done to investigate their performance during long-term operation. Myoelectric control (MC) provides manipulating commands using muscular activities produced by user's hand motions. It can be used by people with motor disability to communicate with electronic devices, e.g. prosthesis, wheelchair, and video game console, provided that it keeps long-term stable performance [1,4]. So the stable performance of MC is vital for long-term applications. The performance is measured in three aspects: accuracy, intuitiveness and response time [4], among which accuracy is more fragile in long-term operation due to physical and physiological changes. This paper investigates accuracy of myoelectric control applied to video game during real-time and long-term application and proposes adaptive schemes to keep it stable.

Game industry is growing rapidly. Diversified digital video games have entered thousands of homes worldwide and welcomed by people with different ages, gender and capabilities. They adopt sophisticated consoles to enjoy playing game. However, disabled people have huge difficulty to use such conventional control panels. It becomes necessary to design novel interfaces suited for people with motor disability or deficiency and myoelectric control based consoles is an option to do so.

Building a myoelectric control with long-term stable performance is a challenge, since MES is inherently a non-stationary signal and has user-dependent and time-variant properties. For pattern recognition based myoelectric controls, it is necessary to train MES patterns, model the changes and compensate potential changes during a long-time operation [2]. A closed loop control system can play such a role and provide a stable performance using feedback sensory information. Visual and stimulated sensory signals (towards the body) are two feedbacks that could be used to keep stable performance. However, visual feedbacks that continuously involve the mind are not convenient for long-term applications. Meanwhile, the stimulated sensory signal is not always cost effective and practical. For example, when we grab an egg, we do not think about how hard we should grasp after we have gained such experience. Instead, our nervous system automatically takes care so that we can grab an egg without breaking or dropping [5].

Adaptive control, which involves modifying the control criteria to cope with parameter changes, is another option to keep a

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stable performance. Having a proper model of deviations in MES patterns is a key issue to stabilise the accuracy of myoelectric control. The model has to distinguish the regular changes that represent various patterns (i.e. commands) from unwanted changes (i.e. deviations) causing accuracy decline. Meanwhile, it should discriminate transient changes, which are highly unpredictable and even contradictory [4], from steady state changes.

Changes in MES patterns are either gradual or significant. The gradual changes can be resolved by adaptive schemes otherwise the system would need a re-configuration. Some physical factors can cause either gradual or significant changes. For instance, sweating and electrode displacement can lead to slight and major changes, respectively. Geometrical factors, which indicate the relative position of active and detectable motor units, the signal's non-stationarity and fatigue, are other reasons of changes in MES patterns.

Fatigue is a time-related factor that leads to gradual performance variations. It can be named as the dominant factor that affects steady states of MES in long-term operation [6,19]. Fatigue is a concept determined by two dimensions: psychological and physiological [7]. In physiology, fatigue is usually defined as the loss of voluntary force-producing capacity during exercise, and is not necessarily accompanied by self-perceived fatigue, which is known as psychological concept. An important problem in interpreting changes during fatiguing contraction is that it is not always clear whether a change is a direct result of the exhaustion or whether it is an adaptation. Meanwhile, frequent distractions and re-attentions, which can be of psychological fatigue, boost variations in MES. Myoelectric signals provide useful information about the peripheral level (i.e. in the muscle tissue) of fatigue rather than its central level (i.e. central nervous system). Manifestation of fatigue can be studied by means of signal amplitude, signal frequency and muscle conduction velocity (CV) [6,7].

Fatigue has mostly been studied in sustained contraction, while the muscle length and tension are hold constant. During non-maximal voluntary sustained contraction, signal amplitude usually increases considerably due to the recruitment of extra motor units and increasing in firing rate of motor units. Both are mechanisms to cope with the declining force output. In contrast, during high and maximal voluntary sustained contractions, the amplitude usually declines. Furthermore, in sustained contractions, the muscle conduction velocity (CV) decreases with fatigue due to the change in the metabolism of cellular environment, and this phenomenon is reflected as a shift to the lower frequencies of signal spectrum. Hence, signal frequency is known as the main manifestation of fatigue in MES under static conditions [8].

During unconstrained contractions, however, when the muscle length and/or tension are free to vary, characteristic frequency measurements are influenced by factors other than fatigue. Geometrical factors, which indicate the relative position of active and detectable motor units, significantly change the signal frequency spectrum that may incorrectly be attributed to physiological factors. High degree of non-stationarity of signal is another major problem in dealing with unconstrained contraction. Moreover, MES may suddenly change its spectral properties due to different limb states, which may be difficult to investigate with classical spectral techniques. Time-scale methods, particularly Wavelets and Cohen's class, are introduced to cope with signals' non-stationarity and sudden changes. Furthermore, direct measurements of CV are difficult to attain accurately during unconstrained contractions, possibly because of muscle innervations zone migration and/or end-effects [6,8].

Many literature study manifestation of fatigue in MES in unconstrained contractions [9–13]. They can be used to model the changes in MES patterns during playing video games. Karlsson et al. [9] applied different time-scale methods to analyse MES during dynamic contractions, and found that continuous wavelet transform (CWT) provides more accurate estimation comparing with short-time Fourier transform (STFT), Wigner–Ville distribution, and Choi–Williams distribution. Farina et al. [10] proposed a technique for detection and processing of muscle conduction velocity (CV) during dynamic contraction, and showed that CV decline is reflecting muscle fatigue. Bonato et al. [11] applied Cohen class time-scale transform for assessing muscle fatigue during cyclic dynamic contractions. It was assumed that the non-physiological factors contributing to the MES non-stationarity during dynamic contractions could be constrained and isolated for cyclic dynamic contractions. Al-mulla and Sepulveda [19] proposed an algorithm for automated muscle fatigue detection in sports related scenarios. They applied genetic algorithm for evolving a pseudo-wavelet function for optimising the detection of muscle fatigue on any MES.

Georgakis et al. [13] showed that average instantaneous frequency (AIF) outperforms the conventional mean and median spectrum frequency in fatigue analysis of sustained contraction. MacIsaac et al. [8] proposed a method to estimate a measure of fatigue using MES time domain features. They applied artificial neural networks (ANN) to tune parameters of a function mapping MES features to a measure estimating fatigue during dynamic contractions. The proposed ANN was capable to be used in real time but had to be trained before application. Oskoei and Hu [12] studied frequency shift as manifestation of fatigue in unconstrained contractions during playing video games. They examined spectral and time-scale MES features and showed significant decline in signal frequency during fatigue.

In this paper, we investigate the effect of fatigue-based deviation (i.e. steady state) in MES patterns during real-time and long-term muscular activities conducted to play a video game. We employed a pattern recognition based myoelectric control for a video game, in which the player drives a car in a route with randomly appearing obstacles, using five hand's motions. The generated MES patterns, corresponding to the hand states, were recorded along with goniometry sensory data indicating bending angle of the hand. Transient states were excluded to reduce the effect of dynamic contractions and just steady states were used in the study. The hand's physical states and the corresponding MES patterns were simultaneously examined to detect deviation in MES patterns in long-term activities. This was called supervised method. In the unsupervised method, we examined MES patterns without using goniometry data. The most informative MES samples, known as support vectors (SVs), were marked to model the changes of boundaries between MES patterns corresponding to hand states. The detected changes in MES patterns were used to develop adaptive control. It is shown that the adaptive myoelectric control keeps the performance stable and provides higher score in long period of the game.

The rest of paper is organised as follows. Section 2 describes materials and methods applied to develop adaptive myoelectric control for a video game and experiments conducted to evaluate it. The experimental results are presented in Section 3, and the discussions are presented in Section 4. Finally, Section 5 contains a brief conclusion and potential future works.

2. Materials and methods

A pattern recognition-based myoelectric control was applied to a video game. Comparing with other activities, such as manipulating prosthesis or driving electric wheelchair, during playing video game, we could involve the subjects in an attractive and long-term muscular activity with minimum danger for them. The subjects were encouraged to gain the highest score as far as possible, so the game was carried on by the subjects until they were not able to get more scores continuously.