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A novel recognition system for human activity based on wavelet packet and support vector machine optimized by improved adaptive genetic algorithm

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ABSTRACT

A new human activities recognition system based on support vector machine (SVM) optimized by improved adaptive genetic algorithm (IAGA) and wavelet packet is proposed. Wavelet packet transform (WPT) is applied to extract the signatures from various actions. SVM is a powerful tool for solving the classification problem with small sampling, nonlinearity and high dimension. Genetic algorithm (GA) is employed to determine the two optimal parameters for SVM with highest predictive accuracy and generalization ability. Moreover, the IAGA adopts the dynamic cross rate and mutation rate according to the group fitness, thus effectively avoiding the disadvantages of the standard GA, such as premature convergence and low robustness. The average recognition accuracy rate goes up to 97.6%. In addition, the result of suggested method is also compared with other feature extraction methods which further demonstrate the superiority of WPT and generalization ability of IAGA. The aforementioned results clearly demonstrate that the proposed method is superior to the traditional method in activity recognition.

1. Introduction

The past decade has witnessed a rapid proliferation on human activity recognition as it has many potential application domains such as human–computer interface (HCI), automated surveillance, and physical security both in the civilian and military operations [1]. For instance, patients with diabetes or other mental pathologies could be monitored to detect abnormal activities and thereby undesirable dangerous behaviors could be prevented. Likewise, intrusion detection based on activity recognition is helpful to support decision making in military [2]. Nevertheless, complex and highly diverse human activity have posed challenges to providing accurate and opportune information on people's activities and behaviors.

Most current successful research has concentrated on classifying simple human activities. Recognizing complex human body activities remains an inspiring and active field [3].

Much work has been done in the area of human activity recognition. Since the movements of human bodies are the main character of their activities, many researches focus on the wearable system, especially the tri-axial accelerometer that can be used to estimate the velocity and displacement well [4–6]. Although the research result on wearable computing has been fruitful, the users of those systems do not always feel comfortable wearing sensors [7,8]. Another group of researchers has attempted the full three-dimensional reconstruction of human actions from video and image sequences, but these kinds of optical methods of surveillance are limited to environment conditions such as haze, fog or at night [9].

The use of impulse radio ultra wide band (UWB-IR) is another unique method to detect and monitor human

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actions in recent years. Since UWB-IR has many advantages such as well penetration ability, low power cost and high temporal and spatial resolution, several researches have shown a promising prospect on detecting and classifying human actions. Considering the electromagnetic character, there is literature focusing on the micro Doppler of the different activities [10,9,11], which is an efficient way to track the moving target but not the static by capturing the micro-Doppler signatures. Moreover, Liang et al. investigated target detection using UWB radar sensor network and signal processing [12–19]. These studies focused more on the foliage penetration or target detection than the recognition of concrete target types. Zhai et al. analyzed the target recognition and classification by measuring and processing bi-static UWB radar signal in [20]. The basic statistical channel properties are extracted for classification, however, the statistical character may miss some important information.

In this paper, we proposed a novel method to detect and recognize human actions based on the received waveforms collected by a UWB communication system [21,22]. In our studies, the received UWB-IR signal is sensitive enough to detect changes in activity types. Through observing the shape change of the received waveforms, the tiny difference of the various gestures can be obtained. Moreover, wavelet packet transform is one of the most popular candidates of the time–frequency analysis tool which has variable time/frequency resolution. So we extract the typical signatures of the different activities by calculating the wavelet packet sub-bands energy of the received signals [23,24]. Subsequently, we develop activities identification algorithm based on machine learning techniques, where a support vector machine (SVM) [25,26] is introduced to classify the different activities. Finally, due to the parameters of SVM set in advance which affect the final result, a novel improved adaptive genetic algorithm (IAGA) is proposed to optimize the parameters of SVM [27–29].

The objective of this paper is to develop a method of IAGA–SVM combined with WPT-based feature extraction to recognize the human activities, in which IAGA is applied to optimize the two parameters of SVM. The remainder is organized as follows. Section 2 provides a brief overview of wavelet packet transformation based-feature extraction. Section 3 describes the basic idea of support vector machine. In Section 4, SGA, IAGA and optimization procedure to the SVM are presented. The recognition model for human activity is described in Section 5. The concrete experiment results and relevant analysis for activity recognition based on IAGA–SVM are presented in Section 6. Finally, conclusions are summarized in Section 7.

2. Wavelet packet transformation-based feature extraction

WPT is a relatively new signal processing tool that can be considered as an extension of wavelet transform (WT). In WPT, both the low-frequency and the high-frequency components of the signal can be decomposed into equally spaced sub-bands. This flexibility of a rich collection of abundant information with arbitrary time–frequency resolution allows extraction of features that combine stationary and non-stationary characteristics. WPT has established numerous applications in fields such as signal processing and pattern recognition in the previous existing literature [23,24].

Now given orthogonal scaling function and wavelet function can form two scales equations [23]:

$$\begin{cases} \phi(t) = \sqrt{2}\sum_k h_k \phi(2t-k) \\ \psi(t) = \sqrt{2}\sum_k g_k \psi(2t-k) \end{cases} \tag{1}$$

where h_k, g_k are a pair of conjugate mirror filters to further promote the two-scales equations, the recurrence relation can be defined as follows:

$$\begin{cases} w_{2n}(t) = \sqrt{2}\sum_{k\in z} h_k w_n(2t-k) \\ w_{2n+1}(t) = \sqrt{2}\sum_{k\in z} g_k w_n(2t-k) \end{cases} \tag{2}$$

$n = 0$, $w_0(t) = \phi(t)$, $w_1(t) = \psi(t)$. The above definition of the function consists of a collection $\{w_n(t)\}_{t\in z}$; it is a certain set of functions including a link with the scaling function $w_0(t)$ and the mother function $w_1(t)$.

Several statistical parameters can be extracted from the coefficients calculated by WPT. In this paper, the sub-bands energy is used as the characterization of the signal. The energy in each frequency sub-band can be defined as below:

$$E_j^n = \sum_{i=1}^{N} x_j^n(i)^2 \tag{3}$$

where N is the number of the wavelet packet coefficients in the frequency sub-band, and the $x_j^n(i)$ is the wavelet coefficient. Consequently, the feature vector can be constructed from all the sub-frequency band energy as:

$$F = [E_j^0, E_j^1, \dots, E_j^{2^j-1}] \tag{4}$$

where j represents the order of the decomposition [28].

The total energy can be given as:

$$E = \sum_{n=0}^{n=2^j-1} E_n. \tag{5}$$

In consequence, the relative WPT energy which quantifies the probability distribution of the spectral energy is:

$$F_r = [E_j^0/E, E_j^1/E, \dots, E_j^{2^j-1}/E]. \tag{6}$$

3. Support vector machine

The SVM [26] performs the activity recognition for two-class problems by using the separating hyper-plane. The determination of SVM classification is to find an optimal separating hyperplane by maximizing the margin between the separating hyperplane and the closet data points of the training set. Let $\{x_i, y_i\}_{i=1}^n$ be the training sample set,