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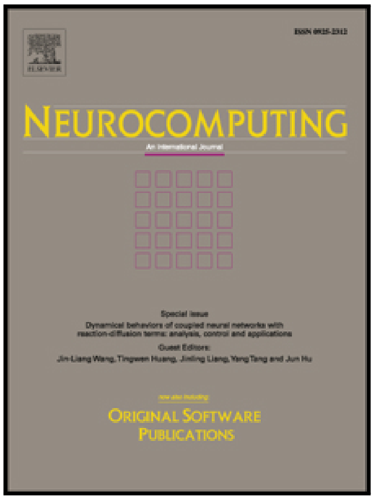

A Real-Time Spike-Timing Classifier of Spatio-Temporal Patterns

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A Real-Time Spike-Timing Classifier of Spatio-Temporal Patterns

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***Abstract*—Considering the problem of recognizing non-verbal cues in Human-Robot Interaction applications, this paper proposes a novel real-time unsupervised spike timing neural network for recognition and early detection of spatio-temporal human gestures. Two spiking network classifiers one based on Izhikevich neuron model, and the other one based on Integrate-and-Fire-or-Burst neuron model have been implemented in CUDA, and allow the classification to be performed in real-time. To evaluate the performance of this proposal, we test the case of a physical robot observing air-handwritings of human gesture. The proposed approaches run in real-time, thus they are suitable for human-robot applications; they allow real-time early classifying human gestures and actions while they require a very small number of training samples. In comparing to other prominent techniques, our approaches demonstrate superior accuracy and are suitable for early classification of different types of human actions in time-sensitive mobile applications such as robotics.**

***Index Terms*—Spike timing neural network, STDP, Real time classifier, Izhikevich spiking neuron model, Integrate-and-Fire-or-Burst neuron model, HRI, CUDA.**

I. INTRODUCTION

FOR a successful replication of the smooth human interactions in robotics, it is essential to extend the communication model from sole reliance on verbal communications towards inclusion of non-verbal cues as well. Patterns such as body and hand gestures, gaze, and facial expressions are extensively used in social interactions, as they carry intentional meanings of a person's own goals [1].

This paper addresses the problem of learning and classifying such cues, abstracted as spatio-temporal patterns. While people can quickly recognize such gestures and predict others' intentions based on observed movement patterns, the same task is more challenging for an autonomous robot system. This challenge is further emphasized in processes involving cooperative actions, such as smooth passing of objects between robots and human counterparts [2], navigation in crowded environment [3], and assistive applications of robotics [4]. In order to facilitate and support such interactions, which naturally happen between people for domains in which humans and robots interact with each other, the ability for real-time recognition, early detection and prediction of human gestures becomes of key importance.

The first step toward this goal is to be able to understand gestures in real-time. In collaborative scenarios, it is crucial for robots to understand what their human teammate is doing, and also be able to recognize their intentions early on in order to proactively help them complete the task [5]. This step can be implemented as a classification task, which not only accurately identifies the type of observed actions, but is also capable of detecting such actions before their completion. Therefore, both real-time processing and early classification are important features of a robotic system in human-robot interaction domains. The work proposed in this paper brings several contributions that address important challenges in spatio-temporal pattern classification.

The first challenge relates to the large number of training examples that is typically required by current state of the art classification techniques [6], [7]. As a benchmark for non-verbal cues relevant to Human-Robot Interaction, this work considers air handwriting, which is the act of writing digits and characters in the air. Air handwriting encompasses the fundamental characteristics of human activity patterns such as the effect of order and sequences of motions, hence it represents the generic form of spatio-temporal patterns in human gestures and actions. The results obtained from this benchmark indicate that the approach proposed in this work *relies on a very small number of training examples*, while giving results that are comparable with those provided by the current state of the art methods. This is achieved through the use of a spike-timing neural network (SNN) with axonal conductance delays. The network is repeatedly stimulated with the same (small) set of input patterns and through an *unsupervised learning* stage based on spike-timing dependent plasticity (STDP) is able to capture the key features of each pattern class.A second challenge relates to the ability to classify observed movement patterns in real time, as would be necessary for human-robot social interactions.

This work develops two *parallelized CUDA version of a spike-timing neural network* with *Izhikevich neuron* as well as *Integrate-and-Fire-or-Burst neuron* that continuously performs classification, *in real time*, during the time the movement pattern is observed, and also *enables the early classification of the movement* well before the movement pattern is fully completed by the human. This approach has been validated on a physical PR2 robot system for which a human user uses her hand to draw (in the air) the set of digits between 0 and 9.

We also test our approaches on 3 datastes including 6dmg digit and character gesture datasets [8] , as well as our in-house recorded digit gesture dataset. As a measure of accuracy of our real-time spiking neural network classifiers, we trained them with 6dmg digit gesture dataset and validated on a set of digits (0 through 9), drawn by a human hand in air, in

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