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RT-ICAR-NA-2012-05	**06 2012**

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Rapporto Tecnico N.:	***Data:***
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collaboratori dell'ICAR, in alcuni casi in un formato preliminare prima della pubblicazione definitiva in altra sede.

Abstract—The autistic spectrum disorders (ASD) are behaviorally-defined developmental disorders of the immature brain which affect three domains of behavior: sociability and empathy; communication, language and imagination; and mental flexibility and range of interests. Main symptoms include motion disorders and stereotyped behaviors.
This paper presents a neural-network based approach for the analysis of stereotyped motion disorders of patients with ASD. Specifically, monitoring is realized by means of tri-axis accelerometers applied to the patient's wrists. Signals obtained by accelerometers are pre-processed to obtain features that, in turn, are passed to the neural network that classifies the current observation in order to detect stereotyped motions. Results are under validation at the Department of Child Psychiatry at Children's Hospital Santobono-Pausilipon in Naples.

I. INTRODUCTION

Autism is a group of developmental brain disorders, collectively called autism spectrum disorder (ASD). The term spectrum refers to the wide range of symptoms, skills, and levels of impairment, or disability, that children with ASD can have. Some children are mildly impaired by their symptoms, but others are severely disabled [1].
Thirty years ago autism was considered to be a rare child- hood disorder most often associated with severe intellectual disabilities, lack of social awareness and the absence of meaningful expressive language [2]. Today, the spectrum of autistic disorders (or Autism Spectrum Disorder, ASD) is now recognized as a set of common developmental disorders, with an estimated prevalence of about 1 in every 110 children in the U.S. [3].
Symptoms of autism spectrum disorder (ASD) vary from one child to the next, but in general, they fall into three areas:
1) Social impairment; 2) Communication difficulties; and, 3) Repetitive and stereotyped behaviors [1].
This paper focuses on the automatic recognition of repetitive and stereotyped behaviors,

with a specific emphasis for motion disorders like hand flapping or hand hitting ears, which are The proposed approach uses tri-axis accelerometers applied to patient's wrists to get motion information. In case of motion disorders signals caught from accelerometers reflects specific patterns. Thus, some features extracted from signals are used to classify the motion by a neural network. The rest of the paper is organized as it follows. Section II introduces some related work. Section III describes the proposed approach and reports some results. Finally, Section IV concludes the paper.

II. Related work

Different Artificial Intelligence techniques are adopted to detect human activities in smart environments [4]. Among the others, Hidden Markov Models and Neural Networks [5] are major solutions in case of gesture recognition.

To the best of our knowledge, there is no published paper on the automatic recognition of motion disorders of patients with ASD.

To develope our system, we chose to adopt neural networks because they are more flexible models that can dynamically adapt to changes.

Neural networks have been adopted for other applications of gesture recognition by means of signals acquired by ac-celerometers. Here we report some related work.

Arce and Valdez [6] used the Nintendo Wiimote controller and built an artificial neural network to recognize five gestures: Circle, Square, Trinangle and the letters S and Z.

A similar approach has been adopted by Kim et al. [7] to design a dance game controller. Starting from a basic posture, the user can move her hands Up, Down, Left and Right.

Ahsan et al. [8] trained an artificial neural network with data extracted from electromiograpiphy signal in order to recognize hand motions for advanced humand computer interaction mechanisms. In this paper, we focus on stereotyped motion disorders such as Repeated hand Hitting against the ear (RH). This iis a typical motion disord for a patient with autism who tries to isolate himself from the sourrounding environment.

Fig. 1. TI eZ430-Chronos

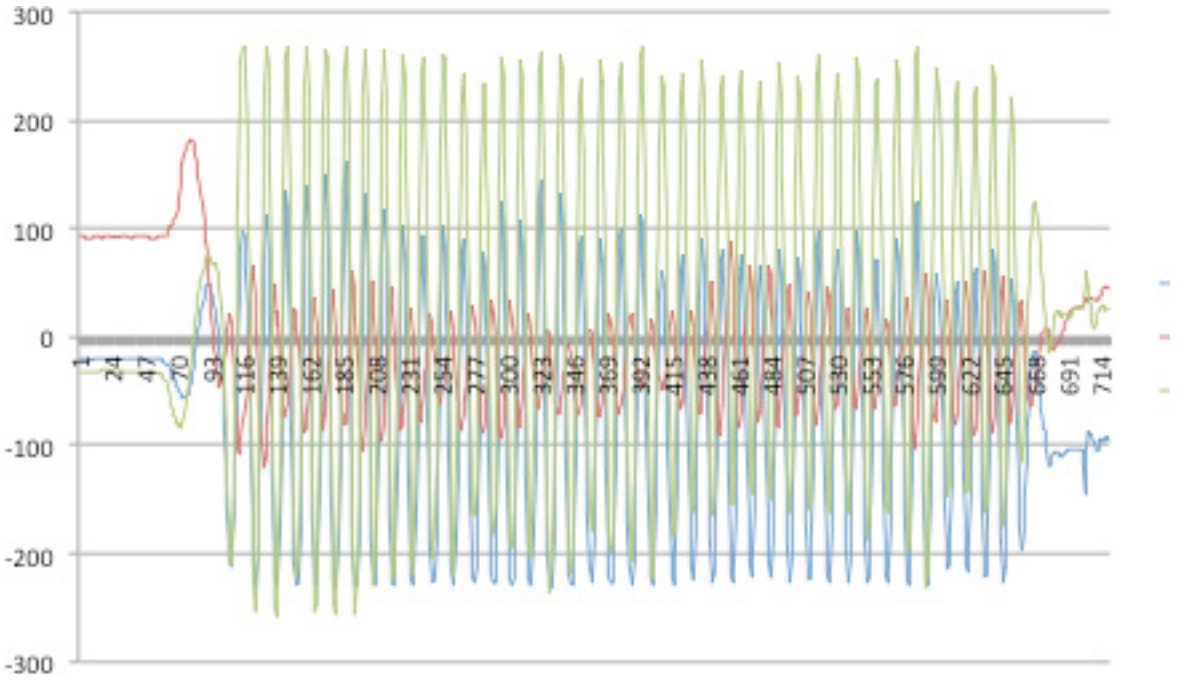

Fig. 3. Example of motion disorder

III. PROPOSED APPROACH

A. Data acquisition

In order to acquire motion data, we apply accelerometers to the patient's wrist. The device is shown in figure 1.
The eZ430-Chronos is an integrated, wireless development system that provides a complete reference design for devel- opers creating wireless smart watch applications. Chronos is a reference platform for many applications, such as wireless watch systems, personal displays for personal area networks, wireless sensor nodes for remote data collection and other applications. It includes a 96 segment LCD display and provides an integrated pressure sensor and 3-axis accelerometer for motion sensitive control. The Chronos to act as a central hub for nearby wireless sensors such as pedometers and heartrate monitors. The eZ430-Chronos offers temperature and battery voltage measurement and is complete with a USB-based CC1111 wireless interface to a PC. The eZ430-Chronos watch may be disassembled to be reprogrammed with a custom application and includes an eZ430 USB programming interface.
Such a device comes with a DLL control driver; however, we used the RXTX library [9]. RXTX is a native lib providing serial and parallel communication for the Java Development Toolkit (JDK). All deliverables are under the gnu LGPL license.
Figure 2 shows the results of almoast one hour continuous monitoring. Red circle denotes an episode of motion disorder of the type RH, which is also reported in figure 3.

B. Feature extraction

Signals reported in figure 2 are pre-processed in order to extract features usefull for classificaiton. In particular, the following features are calculated:
Mean Absolute Value, which is obtained from the avarage of the absolute value of each signal.

$$MAV = \frac{1}{N}\sum_{n=1}^{N}|x_n|$$

Root Mean Square RMS, which is also known as the quadratic mean, is a statistical measure of the magnitude of a varying quantity.

$$RMS = \sqrt{\frac{1}{N}\sum_{n=1}^{N}{x_n}^2}$$

Variance VAR, which is a measure of how far a set of numbers is spread out. It is one of several descriptors of a probability distribution, describing how far the numbers lie from the mean (expected value).

$$VAR = \sqrt{\frac{1}{N}\sum_{n=1}^{N} {x_n}^2}$$

Standard Deviation SD, which shows how much variation or ”dispersion” exists from the average (mean, or expected value).
A low standard deviation indicates that the data points tend to be very close to the mean, whereas high standard deviation indicates that the data points are spread out over a large range of values.

$$SD = \sqrt{\frac{\sum_{n=1}^{N} {x_n}^2}{N} - (\frac{\sum_{n=1}^{N} x_n}{N})^2}$$

Waveform Lenght WL, which is the cumulative lenght of the waveform over the time fragment. WL is related to the waveform amplitude, frequency and time.

$$WL = \sum_{n=1}^{N} |x_{n+1} - x_n|$$

Zero Crossin WZC, which is the number of times that the amplitude value of the signal crosses the zero y-axis.
All these features are computed for each (x,y, and z) signal. In addition to this, we have also computed covariances among such signals, which, however, have not shown to be relevant for classification. C. Neural Network based classificator In order to identify motion disorders, we built a clas- sificator based on an artificial neural network. The system architecture was designed adopting KNIME [10], an open-source environment for data integration, processing, analysis, and exploration.

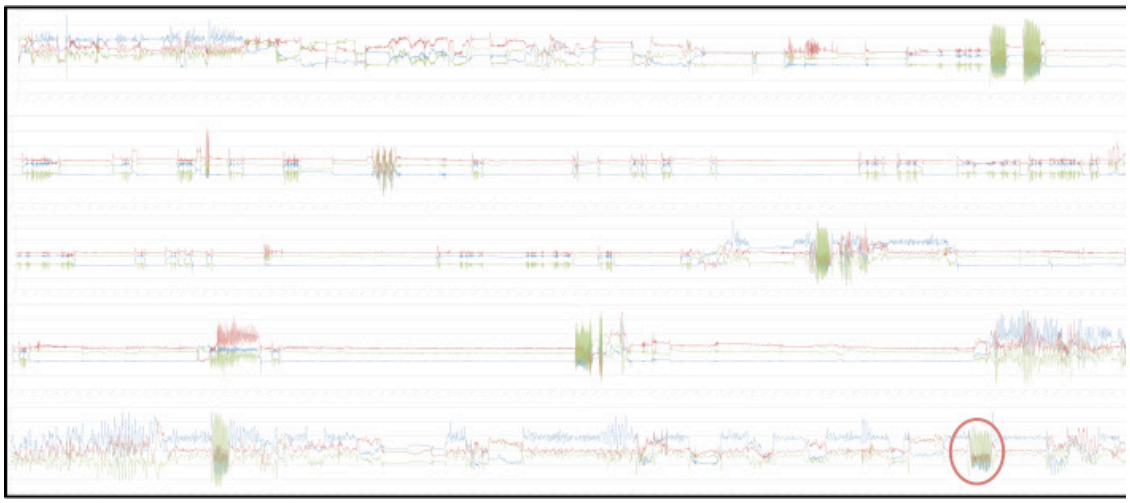

Fig. 2. Monitoring

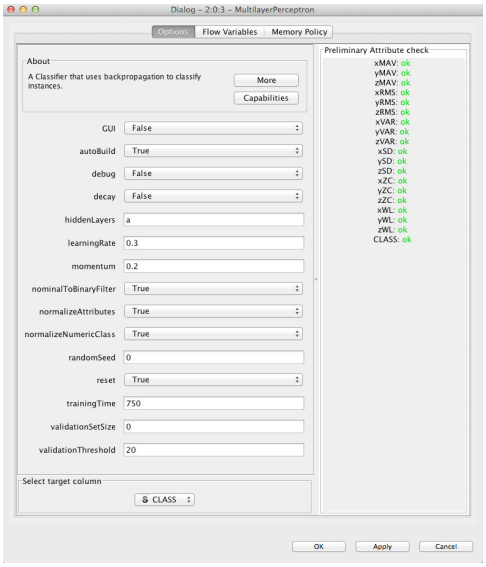

Fig. 5. Neural Network parameters

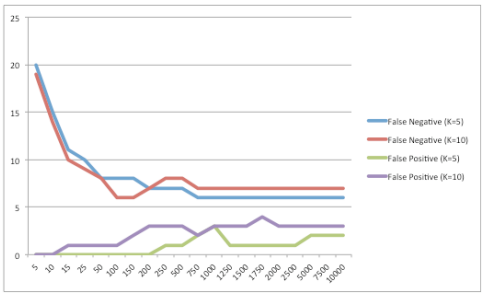

Fig. 6. Percentage of errors while varing the number of epochs

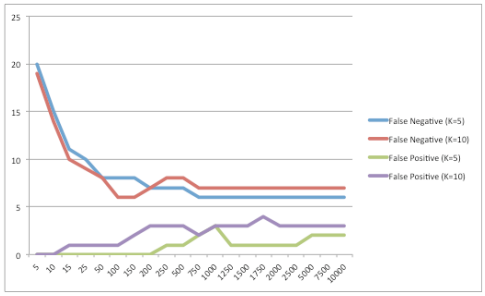

Fig. 7. Missclassifications while varing the number of epochs

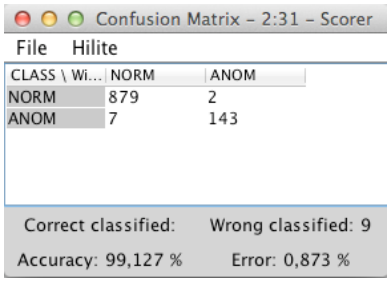

Fig. 8. Performance of the neural network classificator

I V. CONC L US I ON

In this paper we have presented an artificial neural network based approach to detect stereotyped motion disorders inchildren with Autism Spectrum Disorders.
Preliminary laboratory results encourage to adopt such an
approach in real case studies.
Future work is going to deploy the monitoring system at the Department of Child Neuropsychiatry at the SantobonoPausillipon Children Hospital. Future work will also compare

the performances of the neural network with others machine learning techniques such as Bayesian networks.

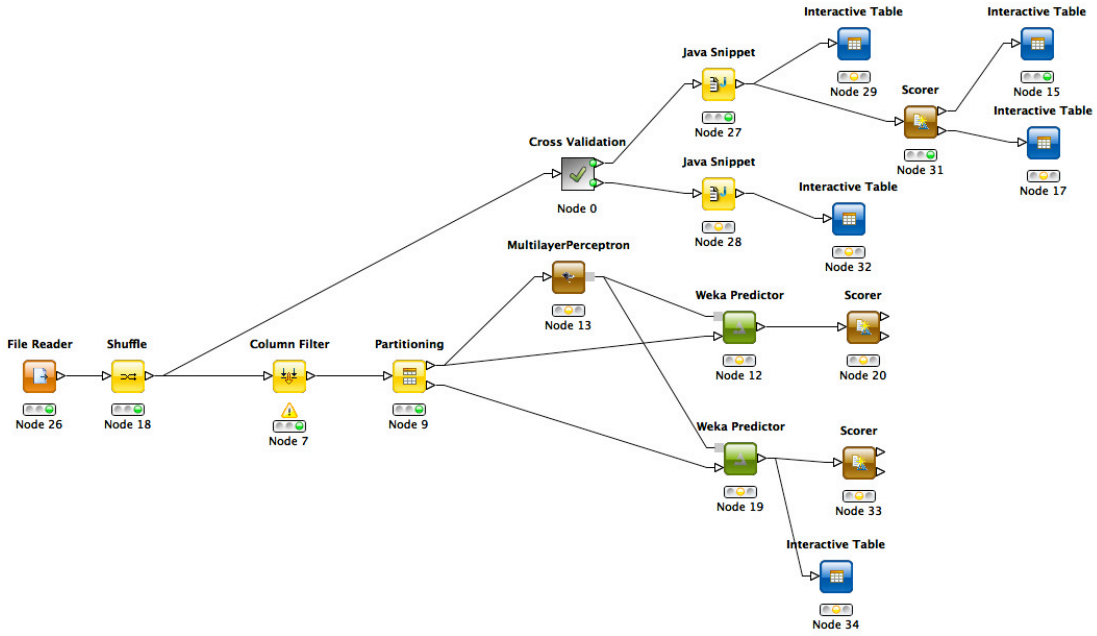

Fig. 4. Neural Network based classificator

The final objective, however, is to realize a full context-aware environment [11], which should be able to detect patient anomalous behaviors and try to attract his attention and report him in a safer situation.

AC KNOWL E DGME NT

Authors wish to thank clinicians from the Department of Child Psychiatry at Childrens Hospital Santobono-Pausilipon in Naples whose feedback is enabling the improvement of results of this research activity.

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