Augmented Reality and Novel Virtual Sample Generation Algorithm Based Autism Diagnosis System

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Certificate of Authorship and Originality

I, Mohammad Wedyan, declare that this thesis is submitted in fulfilment of the requirements for the award of PhD degree, in the school of Biomedical Engineering, Faculty of Engineering and Information Technology at the University of Technology Sydney. This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis. This document has not been submitted for qualifications at any other academic institution.

This research is supported by the Australian Government Research Training Program.

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Mohammad Wedyan

Date: 16/04/2020

Dedication

To the Spirit of My Father

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May Allah grant him his highest paradise (Amen).

Mohammad Wedyan.

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Abstract

Creating a friendly and effective environment for diagnosing autism in children is a challenging research topic. This thesis proposes a diagnostic system for autistic children based on their upper limb movement. This new system has been designed based on using Augmented Reality (AR) to provide a friendly, effective, and interactive environment to perform the required diagnostic exercise and record the movements without any tension.

The other challenge in relation to this research topic is the size of the available clinical data. The clinical samples are generally small in this field of medical research due to the intrinsic prevalence of disorders and other factors such as elevated costs for patient recruitment and the limited time available for evaluations. Small sample sizes significantly limit the ability of pattern recognition methods to correctly predict or classify the data and this in turn leads to inaccurate classification performance. Thus, this thesis focuses on providing a technique to deal with the small data size and this is based on augmented data from a small real dataset.

The proposed new system employs many algorithms for diagnosing autistic children based on classification of the collected data from the AR system. For example, Linear Discriminant Analysis (LDA) is used for extracting the features from raw data, while Extreme Learning Machine (ELM), Support Vector Machine (SVM), and Softmax algorithms are used for classification. Also, the thesis uses deep neural networks, which are regarded as successful learning tools for building nonlinear models.

A robust classification model and a deep learning neural network needs a large dataset. This is because classification models are often unstable when they employ small datasets. Therefore, this thesis proposes a novel Virtual Sample Generation (VSG) algorithm in order to solve this issue. In respect of autism detection, it is difficult to obtain a large

dataset. The results show that when virtual samples are generated based on small samples, the accuracy of the autism diagnosis is enhanced from (84%-95%) compared to traditional methods. In addition, the proposed technique has a proven ability to be generalised as it can be tested with benchmark datasets such as the Breast Tissue dataset and Escherichia coli (E-coli) dataset. Indeed, the results show that the classification model that uses virtual samples is more accurate than to the model that uses original training data without virtual samples.

The required data for the system testing has been collected from different sources; we gained the ethical approval number ETH18-2710 from the University of Technology Sydney, titled "Implementation of an Augmented Reality Game to Track Upper Limb Movement in Autistic Children." In addition, this research was conducted in collaboration with the National Database for Autism Research (NDAR) in the USA, and the Scientific Institute IRCCS Eugenio Medea in Italy. Both institutions provided access to the database on the kinematic analysis of upper-limb movement in children with autism and typically developing children.

The main contribution of this thesis lies in designing a new system based on AR for diagnosing autism that does not require wearable hardware sensors. This factor makes the new system more generally applicable and comfortable. Furthermore, this thesis proposes a virtual sample generation algorithm to generate a virtual sample in order to enhance the accuracy of the classification when using deep learning networks that depend heavily on the amount of data. This innovation leads to more accurate diagnostic results.

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Abbreviations

AR	**Augmented Reality**
ASD	**Autism Spectrum Disorder**
DNA	**Deoxyribonucleic Acid**
EEG	**ElectroEncephaloGram**
ELM	**Extreme Learning Machine**
FVP	**Functional Virtual Population**
GA	**General Anesthesia**
HCI	**Human Computer Interaction**
HR	**High Risk for autism**
HRI	**Human Robot Interaction**
IRCCS	**Scientific Institute for Research, Hospitalization and Healthcare**
KBD	**Kashin Beck Disease**
LDA	**Linear Discriminant Analysis**
LR	**Low Risk for autism**
MTD	**Mega Trend Diffusion**
MVN	**MultiVariate Normal synthetic**
NDAR	**National Database for Autism Research**
RG	**Related Group**
SS	**Selected Samples**
SVM	**Support Vector Machine**
TD	**Typically Developing children**
UCI	**University of California, Irvine**

URG	**Unrelated Group**
VR	**Virtual Reality**
VSG	**Virtual Sample Generation**
MRI	**Magnetic Resonance Imaging**
ML	**Machine Learning**
NN	**Neural Networks**
CAE	**Convolutional Auto-encoders**