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MACHINE PERCEPTION IN BIOMEDICAL APPLICATIONS: AN INTRODUCTION AND REVIEW

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ABSTRACT

Rapid diagnosis, need of early prediction and control of diseases shifted the biomedical interest towards Artificial Intelligence (AI). This prominently fosters the collaborative interactions of machine learning in biomedical engineering. AI aims at mining relevant information directly from the derivative physiological data, leads to better performance in comparison to human that is suffered by status of mind and mental variability. Evolutions of new machine learning algorithms are helping the even disrupted pattern of raw physiological data in terms of better classification. The purpose of this study is to create the interest of new researchers in this field by understand the basic technique and applications to aid in their research further.

Key words*- Medical imaging, Waveform analyzing, Classification, Feature extraction,* Artificial Intelligence

Machine learning is the branch of AI, deals with problems considered difficult by traditional computer scientists through the use of knowledge and of probabilities and other kinds of uncertainties. AI has been playing many different roles in scientific research and the literature has shown that AI is promising in solving complex problems in many applications, particularly in areas with huge amounts of data but very little theory. There is recently a growing interest in the application of AI techniques in biomedical engineering and informatics, ranging from knowledge-based reasoning for disease classification to learning and discovering novel biomedical knowledge for disease treatment. Some of AI applications in the field of biomedical are listed in the table.

Integrating artificial intelligence techniques into biomedical engineering:

Some of the steps require to make the system intelligent are given below:

(1) feature selection

(2) visualization

(3) classification

(4) data warehousing and data mining

Feature selection: Size of full feature set in time, sample or in another form is generally a huge data

set and therefore need of reduced set of predictors. The main objective of feature selection is to choose a subset of input variables by eliminating features, which are irrelevant or of no predictive information. Feature selection plays important role to enhance the classifiers performance.
Feature selection techniques have become an apparent need in many biological data mining applications. Some of the most frequent statistical feature extraction techniques are:

a. Auto regression (AR),
b. Discreet Wavelet Transform (DWT),
c. Discreet Cosine Transform (DCT),
d. Eigenvector, Fast Fourier Transform (FFT),
e. Linear Prediction (LP),
f. Independent Component Analysis (ICA)

According to input data type each of above techniques has their own advantages and disadvantages.

Visualization: Dimension of feature can be mapped higher to lower dimension by trading off the desired performance in order to reduced time complexity. There are some linear and nonlinear dimension reductions techniques exist like:

a. PCA (Principle Component Analysis)
b. SVD (Singular Value Decomposition)

Above are the examples of linear mapping whereas Sammon's mapping is one of the example of nonlinear mapping.

Classification: Classification consists of predicting a certain outcome based on a given input. In order to predict the outcome, the algorithm processes a training set containing a set of attributes and the respective outcome, usually called goal or prediction attribute. The algorithm tries to discover relationships between the attributes that would make it possible to predict the outcome. Next the algorithm is given a data set not seen before, called prediction set, which contains the same set of attributes, except for the prediction attribute – not yet known. The algorithm analyses the input and produces a prediction. The prediction accuracy defines how "good" the algorithm is. There are many existing classifiers and produces the different classification results for same problem set whereas the same classifier omits the different results for the different problem set. Some of the classifiers have very wide applications in biological data are:

a. ANN (Artificial Neural Network)
b. kNN (k^{th} nearest neighbour)
c. LDA (Linear Discriminant Analysis)
d. Fast ICA
e. SVM (Support Vector Machine)
f. Naive Bayes classifier
g. Maximum Entropy Method
h. OPF (Optimum Path Forest)

It is necessary to judge the performance of the classifier for the given set of data. The performance analysis depends on many factors like test mode, different nature of data sets, type of class and size of data set. The performance can be measured in terms of accuracy, sensitivity, and specificity.

The Accuracy is calculated as the ratio between the number of cases correctly classified and the total number of cases.

$$\text{Accuracy} = \frac{Ture\ Positive\ Cases + False\ Negative\ Cases}{Total\ Cases}$$

Sensitivity (Se) is the proportion of cases classified positive in relation to all cases tested positive.

$$\text{Sensitivity} = \frac{Ture\ Positive\ Cases}{Ture\ Positive\ Cases + False\ Negative\ Cases}$$

Specificity (Sp) stands for the ratio of correctly classified beats among all beats of a specific class

$$\text{Specificity} = \frac{Ture\ Negative\ Cases}{Ture\ Negative\ Cases + False\ Positive\ Cases}$$

True negatives stands for number of the outputs not belonging to a given class classified as not belonging to the considered class, while false positives stands for the number of incorrectly classified as belonging to a given class. These measures can be computed from a confusion matrix which can be obtained by comparing the expected classification which the ones predicted by a classifier.

Data warehousing and data mining: Data mining is the process of finding patterns in a given data set. These patterns can often provide meaningful and insightful data to whoever is interested in that data.

Advances in data capture, processing power, data transmission, and storage capabilities are enabling organizations to integrate their various databases into data warehouses. Data warehousing is defined as a process of centralized data management and retrieval. Data warehousing represents an ideal vision of maintaining a central repository of all organizational data. Centralization of data is needed to maximize user access and analysis.

Remember that data warehousing is a process that must occur before any data mining can take place. In other words, data warehousing is the process of compiling and organizing data into one common database, and data mining is the process of extracting meaningful data from that database. The data mining process relies on the data compiled in the datawarehousing phase in order to detect meaningful patterns.

Application of AI in Biomedical Engineering:

Diagnosis: In an attempt to overcome limitations inherent in conventional computer-aided diagnosis, investigators have created programs that simulate expert human reasoning. Hopes that such a strategy would lead to clinically useful programs have not been fulfilled, but many of the problems impeding creation of effective artificial intelligence programs have been solved. Strategies have been developed to limit the number of hypotheses that a program must consider and to incorporate pathophysiologic reasoning. The latter innovation permits a program to analyze cases in which one disorder influences the presentation of another.

Medical Imaging: Computer methods of image visualization and recognition are currently very often used in analyzing different types of medical images. Application of syntactic methods of pattern recognition for analysis and early diagnosis of some diseases of selected organs is based on an analysis of selected types of medical images.

The following operations are conducted in the course of initial analysis of the examined images:

1. Segmentation of images.
2. Skeletonisation and analysis of real and verification of apparent skeleton ramifications. Ramifications appearing as a result of skeletonisation may be the artefacts of irregularities of skeletonisation occurring on the external borders of the examined organs or they may be real ramifications in pancreatic ducts.
3. Applying the straightening transformation, transforming external borders of the examined organs from a two-dimensional space into two-dimensional width diagrams showing the contours of the straightened organ. This is the starting point for their further analysis and diagnosis with the application of syntactic methods of pattern recognition.

Waveform Analysis: The biological signals i.e. EEG, ECG, EMG can be analyzed with the help of artificial intelligence for assistance in disease, disorder, generate the control signal etc. Waveform analysis can be done using comparison of obtained waveform with the pre acquired waveform. As AI needs some data to train its network, for that some of exclusive properties called features should be extracted from the biological signal. Further this network undergoes the test for the new data.

Outcome Prediction: A major area of interest in health care policy is outcome prediction, and networks have been used extensively for this purpose. An artificial neural network (ANN) model can predict prostate cancer pathological staging in patients prior to when they received radical prostatectomy as this is more effective than logistic regression (LR), or combined use of age, prostate-specific antigen (PSA), body mass index (BMI), digital rectal examination (DRE), trans-rectal ultrasound (TRUS), biopsy Gleason sum, and primary biopsy Gleason grade [28].

Clinical pharmacology: Drug dosages and drug choices are determined by knowledge of the drug's pharmacokinetics and pharmacodynamics. Often, insufficient information is available to determine the pharmacokinetics of a drug or which drug will have a desired effect for an individual patient. AI may be applied to predictions in clinical pharmacology.

Table: Applications of AI in Biomedical Engineering

Diagnosis	**Reference**
Appendicitis	[1, 2]
Back pain	[3, 4]
Dementia	[5, 6]
Myocardial infarction	[7, 8]
Sexually transmitted disease	[9]
Skin disorders	[10]
Temporal arteritis	[11]
Imaging	
Radiographs (bone lesions, chest, breast)	[12, 13]
PET scans (Alzheimer's disease)	[14]
NMR scans	[15]
Perfusion scans (cardiac, cerebral)	[16]
Analysis of wave forms	
ECGs (anterior vs. inferior myocardial infarction, origin of beats, sinus vs. ventricular ectopic beats, ventricular fibrillation, ventricular strain, ST-T segment classification)	[9, 16, 17]
EEGs (Brain Computer Interface, Robot Control)	[18, 19]
EMGs	[20, 21]
Outcome prediction	
Recovery from surgery (intensive care, orthopedic rehabilitation)	[22]
Cancer (prostate, breast, ovarian)	[23, 24]
Transplantation (liver)	[25]
Heart valve surgery	[26]
Clinical pharmacology	
Predicting: tumor sensitivity to drugs, patient's response to warfarin and central nervous system activity of alfentanil	[27]

CONCLUSION

This paper illustrates the huge flexibility of the artificial intelligence paradigm and its ability, in a wide variety of areas, to perform with significant diagnostic accuracy. The research community has taken great steps towards making AI based systems a practical reality for individuals in the past decades; however, there is still much work to be done.

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