Application of Artificial Intelligence in Microbiology

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Abstract : Artificial Intelligence algorithms are nowadays become part of our everyday lives and widely used in laboratory practices. This study has been undertaken to investigate the use of artificial intelligence (AI) in Microbiology for different purposes. AI tools are using to demonstrate their potential ability in microbiology especially in laboratory practice. AI and machine learning are widely used in almost all area of our daily life. Microbiology field in conjunction with AI are revolutionizing the interpretations of the crucial information from the clinical and laboratory data and converting it into optimized and organized information for diagnostics. This paper provides some popular applications of AI in Microbiology fields.

I. INTRODUCTION

1. Microbiology

Microorganisms are the living organisms such as bacteria, viruses, archaea, fungi, and protozoa which are too small to be observed by the naked eye. Microbiology is the scientific study of microorganisms, those being unicellular, multicellular, or acellular. Microbiology field includes the study of the function, structure and classification of these organisms and researching various methods to exploit and control their activities. It also includes fundamental research on the biochemistry, physiology, cell biology, ecology, evolution and clinical aspects of microorganisms etc. The main sub-disciplines of Microbiology are Bacteriology (the study of bacteria), Immunology (the study of the immune system), Mycology (the study of fungi, such as yeasts and moulds), Nematology (the study of nematodes i.e., roundworms) Parasitology(the study of parasites) Phycology(the study of algae) , Virology, Protistology etc.[1]. Microbiology is mainly used for providing information needed to create vaccines and treatments for diseases, used to develop new methods for controlling illness, used to develop new products against viruses and bacteria etc.

2. Artificial intelligence (AI)

Artificial intelligence (AI) is the intelligence demonstrated by machines, as opposed to the natural intelligence displayed by animals including humans [2]. AI is the branch of computer sciences that is the replacement of human intelligence processes by machines, especially computer systems. Specific applications of AI include expert systems, natural language processing, speech recognition and the development of intelligence machines, thinking and working like humans. In a very simple sentence, it is the smart algorithms which make decisions based on the available data. The basic objective of AI is to enable computers to perform like intellectual tasks of humans such as decision making, problem solving, perception, understanding human communication etc. AI can be used to automate the routine work to reduce the workload of our day to day routine work. Hence AI makes our lives more efficient by saving our valuable time. It is computer science technology that emphasizes creating intelligent machine that can mimic human behavior. Here Intelligent machines can be defined as the machine that can behave like a human, think like a human, and also capable of decision making [3]. AI works by allowing the software to learn automatically from patterns or features in the data by combining the large amounts of data with fast, iterative processing and intelligent algorithms.

In clinical microbiology informatics, Artificial intelligence is an important component. AI solutions have the potential to improve a test's turnaround time, quality, and cost. Therefore Researchers, microbiologists, laboratorians, and diagnosticians are interested in AI-based tools in Microbiology.

II. ARTIFICIAL INTELLIGENCE TECHNIQUES FOR MONITORING DANGEROUS INFECTIONS

During the last few years, to monitor microbiological analysis results or to early identify infection and epidemiological events many infection event observation systems have been developed. A system called “MERCURIO‖” has been developed in University of Bologna in order to help medical practitioners and clinicians to adopt appropriate policies for controlling nosocomial infections. The objectives of the system were the validation of microbiological data and the creation of a real time epidemiological information system. Here, the contributors have applied an expert system, data mining, and statistical techniques[4]. An Expert System for Culture-Based Infection Control called GERMWATCHERT, for detecting nosocomial infections has been deployed at Barnes Hospital[5]. Database software called WHONET 5 is developed for the management of routine microbiology laboratory test results. It focuses on the analysis of data, particularly of the data resulting from antimicrobial susceptibility testing[6]. PTAH system is developed for the analysis of antibiogram data in to help clinicians in the prescription of antibiotics for the treatment of nosocomial infections. Four types of analysis are performed in PTAH such as resistance level over time, hierarchical clustering of antibiograms, similarity of antibiograms, and effectiveness of antimicrobials over time[7].

III. ARTIFICIAL INTELLIGENCE AND DEEP LEARNING TURNS TO ANTIBIOTIC DISCOVERY

Deep learning (DL) is employing neural networks and is a subset of Artificial Intelligence. DL requires uses a training set and are modelled on circuit pathways in the human brain. Important and well-known producers of bioactive compounds such as antibiotics are Streptomyces spp. These bioactive compounds are often encoded as secondary metabolites. Deep learning neural networks have been used to provide with simulated fake secondary metabolite sequences. Many deep learning methods with feature embedding, a technique of representation learning, for compound-protein interaction prediction has been developed. Identifying the drug-target or compound-protein interactions is crucial in drug discovery. The researches and developments in this area provide valuable insights into understanding efficacy and off-target adverse side-effects of drugs [8] [9]. Numerous machine learning methods have been proposed to predict potential compound-protein interactions to narrow the large search space of possible interacting compound-protein pairs and facilitate the drug discovery and development process more accurately.

In the near future, the analysis of different combinations for multiple organisms will be extended so that it will be possible to calculate the union, intersection or difference among networks. Likewise, some researcher groups are investigating the use of deep learning approaches to accelerate manual curation steps. Deep learning alternatives may be advantageous to improve the generalization ability of the classifiers in these fields.

IV. USAGE AREAS OF ARTIFICIAL INTELLIGENCE IN CLINICAL MICROBIOLOGY

The main objectives of a clinical microbiology laboratory are ranging from characterizing the causative agent in a patient's infection to identify global disease outbreaks. These processes are nowadays more intimately connected with AI tools. Effective application of AI tools can increase the timeliness, accuracy and completeness of the testing and also reduce the laboratory workload and cost. The advances of research in this area will further improve patient and public health care in the future[10]. Therefore, it is essential for microbiologists to be familiar with AI tools which can be applied in clinical microbiology. Example Support Vector Machine [SVM], PART, Charge Rule, geno2pheno coreceptor, Position-Specific Scoring Matrix X4R5 [$PSSM_{X4R5}$], and $PSSM_{sinsi}$ etc. Although many tools are already widely used, there are many emerging tools that are not being used but that could be used by the laboratory. The tools can be affectively used for Multiple-Derivative Tracking, Laboratory Electronic Notes, and Results Reporting etc. Numerous advanced Clinical Decision Support Tools have been proposed.

V. ARTIFICIAL INTELLIGENCE CAN IMPROVE DECISION-MAKING IN INFECTION MANAGEMENT

Artificial Intelligence and fuzzy theory are applied in an existing identification and monitoring program Moni/Surveillance[11]. The authors state that routine application of this program will make a significant contribution to quality management at the Hospital. In particular, it will assist the physicians to reduce the rate of nosocomial infection at the ICUs and may therefore potentially serve as a significant cost-reducing measure. Nosocomial infections are much more dangerous than community infections because they are caused by bacteria which have a dangerous (critical) resistance to antibiotics[12]. Lamma et al[4] introduced the MERCURIO system that has been developed in University of Bologna to help medical practitioners and clinicians adopt appropriate policies for controlling nosocomial infections. The main objectives of the system are the validation of microbiological data and the creation of a real time epidemiological information system. The authors have applied an expert system, data mining, and statistical techniques. MERCURIO is an epidemiological database, prepared for storing epidemiological data; a knowledge based system, called ESMIS, used for real time validation and monitoring; and a statistical module, used for performing statistical analyses and identifying outbreaks. Another novel and interested work is presented as defect segmentation of fruits based on colour features with K-means clustering unsupervised algorithm[13]. The authors used colour images of fruits for defect segmentation. The pixels are clustered based on their colour and spatial features, where the clustering process is accomplished. A promising new class of antibiotics is antimicrobial peptides. In [14] the authors by using peptide array technology, two large random 9-amino-acid peptide libraries were iteratively created using the amino acid composition of the most active peptides. The resultant data was used together with Artificial Neural Networks to create quantitative in silico models of antibiotic activity. The authors proved that the quantitative structure activity relationship (QSAR) methodology combined with artificial intelligence/neural network approaches can significantly accelerate the discovery of antimicrobial peptides, even from semirandom starting points based on diverse peptide sequences.

VI. ARTIFICIAL INTELLIGENCE AND PREDICTIVE MICROBIOLOGY.

Predictive microbiology poses several difficulties such as the complexity of the cell physiology; little is known about how it reacts to various extrinsic biochemical and environmental conditions and its characteristic high biological variability must be taken into account[14]. In Complementary and Alternative Medicine essential oils (EOs) are vastly used as natural antibiotics. Daynac et al, tried to evaluate the use of artificial neural networks (ANNs) for the prediction of the antimicrobial activity of EO. The authors proved that ANNs can be reliable, fast, and cheap tools for the prediction of the antimicrobial activity of EOs thus improving their use in Complementary and Alternative Medicine[15].The concept of BioCloud has rapidly emerged with applications related to genomics, drug design, biology tools on the cloud, bio-databases, cloud bio-computing, and numerous applications related to biology and biochemistry[16].

VII. CONCLUSION

Recently, Artificial Intelligence tools are used in almost all areas. In this paper, we have described the applications and uses of AI in Microbiology. In particular, objective of this paper is to be made awareness to the researchers about the various AI technologies which can be used to improve the quality of the research results. Numerous AI tools are used in this area, but very few have been discussed here. The Machine learning algorithms, expert systems, data mining tools etc., have been widely used and proved its efficiency in this field.

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