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Amalgamation of Industry 4.0 and Healthcare within Biomedical Engineering

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Abstract

The research article is important because the article has chosen a unique field of engineering that is biomedical engineering and has subsequently tried to establish a relationship between Industry 4.0 that includes different types of new and innovative technologies along with the healthcare industry. The findings have showcased that IoT has been the most used technology in every industry including the healthcare industry. The result where a pandemic such as TB has been cured because of the implementation of machine learning algorithm used with biomarkers to fetch out a novel treatment for the masses indicates the capability of AI technology in both healthcare and biomedical engineering.

Index Terms

AI Technology, Bioengineering, Biomedical Engineering, Healthcare, Industry 4.0

INTRODUCTION

The article is significant as Industry 4.0 is about integrating different types of new technologies such as Internet of Things (IoT), Artificial Intelligence (AI technology), cloud computing, and others. The healthcare industry is one of the growing industries that has implemented industry 4.0 to curb down the time, cost and also for better solutions. It has been seen that early detections and medical treatment of different diseases is possible through Industry 4.0 in the healthcare industry. Industry 4.0 is considered to be an innovative approach that has helped in manufacturing enhanced quality of medical devices that has been customised as per the patient's requirements [1]. It somehow offered a digital hospital to the patients as well as a monitoring system to fulfill the requirements of the patients in the healthcare industry at optimal cost and also time. The connection with data and data exchange has been established with the help of Industry 4.0.

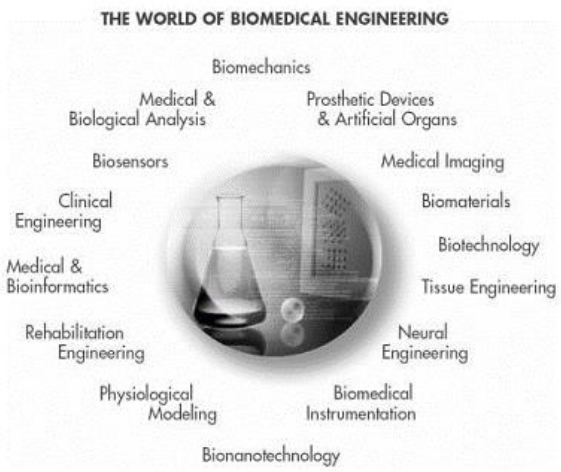

Figure 1: Biomedical Engineering[2]

The relationship between industry 4.0 and healthcare has been formed and understood through the implementation of Industry 4.0 in the specific industry. The aim of the study is to establish a relationship between Industry 4.0, healthcare and also biomedical engineering. Biomedical engineering is considered to be an application of the principles of engineering to resolve the issues associated with health and healthcare. Biomedical engineering requires the application of knowledge, approaches along with concepts of every engineering discipline such as chemical, electrical and others. It can be better understood through the designing of medical imaging modality and creation of devices of medical prosthetics to help out people possessing disabilities [2]. The development of imaging modality and medical prosthetics have been taking place with the assistance of biomedical engineering to help the patients in the healthcare industry. There are different pursuits within the field of biomedical engineering such as creation of diagnostic instruments with the help of blood analysis, creation of diagnostic imaging systems, designing of different biomedical sensors, development of dental materials and others [2]. The other pursuits include development and creation of materials for replacing the human skin, development of telemetry systems as per monitoring the patients.

AI-technology has been witnessed to be implemented in the biomedical sector and utilisation of AI has become common for determining the data types in the biomedical sector. Multi-omics data encompasses proteomics, epigenomics, microbionics, proteomics and others. This type of data has been collected and also analysed. There has been an integration of data that has been taken from mRNA and also from "single-nucleotide polypmorphisms" to develop a model namely, Bayesian integrative model [3]. Therefore, it is clear that the biomedical sector has already implemented AI-based technology to analyse different types of data. There is no synergy witnessed where it has been seen that

automation (as part of Industry 4.0), biomedical engineering along with "health informatics technologies" does not respond to each other.

The above problem of absence of synergy can be better understood through an example on Smart Home that has been demonstrated by Bill Gates. He has depicted the point devices, along with the systems that have been created for monitoring the human activities, tracking of the health status, checking the operations of different home appliances yet these systems possess open loop and subsequently isolated from each other [4]. This is an issue that has been identified between using automation, biomedical engineering and also informatics technologies in the healthcare industry. There are issues with Industry 4.0 as well where it has been found that data integration has become one of biggest hindrances. Data integration is about the combination of various types of data in a single or unified view. The data that has been collected are not enough after collecting it for the single view and are not accurate to provide effective solutions to the patients.

REVIEW OF LITERATURE

Bioengineering and Biomedical engineering

Bioengineering is about application of the principles on biological systems. In this regard, bioengineers are seen to be capable of solving the issues related with artificial tissues, artificial hips, joints and others. [5] stated that there are various bioengineering strategies that revolve around stem cell therapies where the stem cell possesses regenerative potential and also clinical applications. The stem cell therapies are capable enough to change medicine through enabling regeneration of diseases tissues and also of injured tissues and helps in curing certain intractable diseases of the human beings including "muscular dystrophies", "neurodegeneration", diabetes and others. The example of stem cell therapy is effective to study the developmental areas within biomedical engineering that require the application of life science, mathematics and others together.

Biomedical engineering involves the application of the various principles within engineering to solve out the problems in the healthcare industry. [6] argued that biomedical engineering improves the quality of life through improving advanced technologies as well as materials. The various medical equipment along with medical processes have been developed with the help of knowledge within healthcare, engineering and also viology. It has been further seen that those designs of the medical equipment along with processes have further helped in improving the health outcomes. The difference between bioengineering and biomedical engineering is that the various practices of engineering have been applied to different biological systems including healthcare, agriculture and also pharmaceuticals. However, medical engineering is a subset of bioengineering focusing on applying those engineering practices on the healthcare industry only rather than on other industries such as pharmaceuticals and agriculture. The various types of medical devices are basically designed through biomedical engineering.

Application scenarios for implementation of Industry 4.0 in healthcare

IoT has been leveraged for monitoring every facet helping in healthcare implementation within the settings of elder care, home surveillance and also on the rehabilitation system of the healthcare. [7] opined that these setups (of IoT and healthcare implementation) help in producing huge volume and different types of data through enabling big-data technologies. There is another shift that has been witnessed through the usage of cloud infrastructures which is an essential part of Industry 4.0. The cloud infrastructure helps in secure handling of large data. IoT revolves around establishing a connection at anytime and anywhere through focusing on digital identification along with machine-to-machine learning. The objects that have been utilised in the IoT encompasses certain understandings and also connotations associated with Radio-frequency identification (RFID) and "Wireless Sensor Networks" (WSNs) to further understand power consumption, capabilities and others.

IoT Paradigm		Year	Ref.
Internet of Medical Things	(IoMT)	2017	[45]
Internet of Health Things	(IoHT)	2016	[41]
Internet of Nano Things	(IoNT)	2015	[2]
Wearable Internet of Things	(WIoT)	2014	[44]
Internet of m-health Things	(m-IoT)	2011	[46]

Figure 2: Different paradigms of IoT in the healthcare industry[8]

"Wireless Body Area Networks" (WBANs) is used as part of IoT in healthcare and is composed of various wireless devices that includes both sensors and actuators that have been either attached or rather implanted within the human body. [8] argued that IoT is associated with different layers where the perception layer consists of sensors and actuators while transmission layers convey certain sensed information with the upper layer. Computation layers are in charge in terms of processing data while the last layer, that is the application layer, is provided with the charges of utilising IoT infrastructures to attain the goals in healthcare and others. The information flows through these layers in the IoT providing an opportunity to track health status.

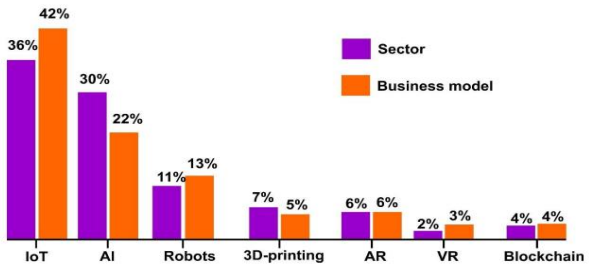

Figure 3: Increasing use of IoT among all the new technologies[9]

Wearable Internet of Things (WIoT) provides automated intervention through telehealth while Internet of Medical Things (IoMT) offers wearable devices. [9] stated that IoT has been efficient for monitoring, service delivery at remote places, real time data of the market and others. "Cloud and Fog Computing" assists in carrying out the operations in a simple way and it does not require resources that allow "pay-per-use billing" (allowing customers to make a purchase on a single amount). Thus, the patients and families in the industry make use of this technology to pay a specific amount within a short time. There is a shortcoming in cloud computing where communication between end device and datacentre is possible rather than involving several users while fog computing is more helpful in healthcare where the technology has improved service delivery in the sector. However, information sharing within medical structures is possible through "Cloud-based Health Information Systems" where both hospitals and patients have benefited with the objective of integrating data in several formats.

Utilisation and identification of new technologies and healthcare areas through Biomedical engineering

Biomedical engineering makes use of engineering practices in the healthcare industry where it is important to understand what type of technology is used while developing and designing imaging modality or prosthetic devices. [10] stated that imaging modalities are categorised through several methods based on generating images which includes ultrasound and radiation that includes X-rays and also "Magnetic Resonance Imaging" (MRI) (an imaging technology producing anatomical images). The designing of imaging modalities has been carried out in a way that it contains the appropriate energy sources which includes light, X-rays, ultrasound, electrons and others. However, after designing it using concepts and knowledge of chemical, electrical and mechanical engineering where every energy source has a connection with a specific type of engineering. The healthcare industry requires these imaging modalities to visualise the body of a human being for the treatment and also diagnostic purposes.

AI technology of Industry 4.0 has certain algorithms in the form of deep learning that have helped in the interpretation of different complex data. [10] argued that AI helps in recognising various complex patterns within the imaging data that further offers quantitative assessments rather than qualitative assessments within the radiographic characteristics. AI methods have been seen to be relying on engineering algorithms where these algorithms have been designed for quantifying radiographic characteristics which includes "3D shape of a tumour" or "intratumoural texture and distribution of pixel intensities". The relationship can be better understood through the fact that biomedical engineering develops medical equipment for the healthcare industry while AI technology identifies the complex pattern within that equipment for diagnosing and medical treatment in the healthcare industry.

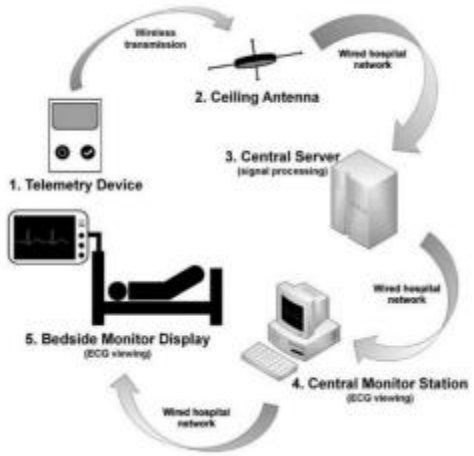

Figure 4: ECG for Telemetry System [11]

Biomedical engineering has a direct association with requirements of the medical devices as well as equipment in the healthcare industry whereas difficult patterns of a disease and diagnosis within that equipment is understood through diverse technologies in Industry 4.0. According to the words of [11], modulation systems have been utilised for transmitting various biomedical signals possessing two modulators such as "Frequency Modulator" (FM) along with "Pulse Width Modulator" (PWM) in a wireless telemetry. Thus, it involves the measurement of different biological parameters within a specific distance while transmitting that data from the generation point to the reception point. There are some psychological parameters that seem to be adaptable within the biotelemetry that includes bioelectrical variables involving ECG, "electroencephalogram" (EEG) and others. The psychological variables are in dire need of transducers that include blood pressure, blood flow, temperatures and others.

The accuracy within a telemetry can be obtained through the preparation of electrode placement, lead, skin, equipment maintenance and also on patient monitoring. The preparation process involves the function of biomedical engineering in the wake of designing it. [12] argued that telemetry systems are also designed with the help of biomedical engineering and are used for monitoring the patients in the healthcare organisations. Telemetry or biotelemetry is an important process that involves recording and also transmitting instrument readings associated with human functions, activities along with condition. Electrocardiogram (ECG) is a tool that helps in the diagnosis of cardiac diseases however, telemetry on the other hand helps in monitoring ECG of the patient. However, an IoT-based telemetry is found to be more productive for offering both indoor and outdoor data of the patients to monitor the indoor and outdoor environment.

MATERIALS AND METHODS

Secondary sources such as journal articles have been found to be beneficial for studying the application of biomedical engineering through merging new technologies and the selected sector to identify the methods [13]. AI systems are

found within biomedical engineering where the AI system has the capability to track molecules in the living cells. The AI system is prepared through a neural network where the technology has been trained to put a single focus on the sample and possess the capability to track fluorescent molecules in the cells. The tracking of different types of molecules makes way for the molecule interactions and at various concentrations that is associated with a fundamental side of cell biology.

There are several researchers from Osaka University and also from RIKEN who have delved into the development of an AI system [14]. In a laboratory, an AI system has been seen to be applied in the imaging as well as analysis within "epidermal growth factor receptors" (EGFRs) in different cells on the plates that have been kept for a particular day. It has been further witnessed that AI systems have the capability to make a distinction between the modified as well as unmodified EGFRs. The experiment has been essential as this experiment has highlighted the potential of the AI technology to identify both the modified and unmodified ones. The neural networks within the AI technology have been found to be helpful for identifying the EGFRs. In this regard, the relation between biomedical engineering and a new innovative technology such as AI has been established through the experiment.

In another experiment, it has been derived that utilisation of "high-resolution liquid chromatography-mass spectrometry (LC-MS)" for testing out the around 191 of the blood samples followed by the discovery of "kynurenine" (Kyn), "Indoleamine 2, 3- dioxygenase" (IDO) and also of the "tryptophan" (Trp) which have offered an excellent result. The experiment revolved around using LC-MS and those discoveries in the form of some effective biomarkers [14]. Application of logistic regression algorithm have fetched the results where the algorithm has helped in identifying the pulmonary TB for further classification of "health control (HC) vs active tuberculosis (ATB)" and "latent tuberculosis infection (LTBI) vs ATB".

RESULTS AND DISCUSSION

Result

The findings will be collected through understanding the application of biomedical engineering in the designing process of medical devices. Assistive technologies that include orthotic and prosthetic devices that have always existed for several centuries. There has been an increase in use of "additive manufacturing technologies" (AMT), namely "3D printing technologies" where 3D printing is considered to be an important part of Industry 4.0. The technologies in 3D printing have emerged with the introduction of a "stereolithography technique". It has been further found that AMTs have been an essential part of rapid prototyping techniques (RPT) that helps in production and preparation of the functional parts of the human body through a three-dimensional model. The techniques have been beneficial and have been applied while manufacturing exoskeleton parts, passive orthoses and others. The development of RPT has evolved to a great extent in biomedical engineering to meet the requirements of the people in need of certain individualised devices [14]. The adaptability rate in biomedical engineering is more to quickly gain an idea on the anatomical shapes of the patients.

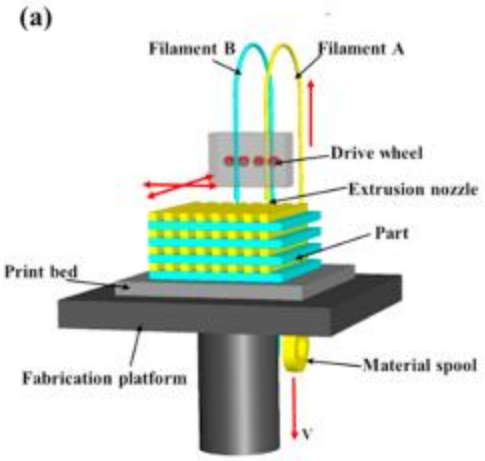

Figure 5: FDM [14]

"Fused Deposition Modeling" (FDM) is considered to be a semi-molten material that has been extruded by an extrusion head that eventually transverses X and Y axis for the creation of the "two-dimensional layer" of that piece that has been manufactured. As FDM technology makes use of materials of low expenses therefore, biomedical engineering has increased the utilisation of FDM for preparing, hand prostheses, upper and also lower limb orthoses, facial prosthesis and others. It is important to note that 3D printing is used along with the use of RPT and FDM within the field of biomedical engineering for designing prosthetic devices [14]. The merging of "computer-aided design" (CAD) and also "computed aided manufacturing" (CAM) have also gained a high momentum within the orthoprosthetic industry.

The application of biomedical engineering can be better understood through innovative diagnostic tests that have been made for patients in healthcare for the purpose of curing a deadly disease in earlier times. The tuberculosis (TB) pandemic has been important to understand the role of AI within biomedical engineering where a study has recognised "transcriptomic biomarkers" on the disease. The techniques on machine learning (ML) have further identified metabolite signatures that have a connection with TB progression. There have been some authors possessing training on the use of "random forest machine learning algorithm" as part of the AI technology to further recognise metabolite signatures that have the capability to foretell the TB progress [15]. This specific experiment where the algorithms of machine learning have the capability to point out the biomarkers within the TB progression has been an effective result indicating a novel treatment for this deadly disease through the algorithms.

There are some other studies that have further mentioned

about certain other algorithms that are capable enough for identifying some biomarkers in connection to some pathological conditions. However, there is an exceptional area where biomarkers cannot be utilised in fixing and also treating of the tumor tissue because those biomarkers do not possess the accuracy that is needed for the purpose of patient stratification along with medical treatment. Conversely, microfluidic systems are effective in case it is utilised with cell biomarkers and the algorithms of machine learning that may offer better outcomes and enhanced stratification for the patients. The result has a tone of 'Turing Test' where a computer's intelligent behaviour may prove to be effective for obtaining human-level performance within certain cognitive-related tasks [15]. Thus, it is evident that either biomarkers with algorithms in machine learning or combination of algorithms with microfludic systems and cell biomarkers may produce effective results. AI has been designed in a way that the programs have the capability to resolve problems as per human thinking skills.

Discussion

Figure 6: 3D Orthotics [15]

Biomedical engineering applies every concept and knowledge of engineering virtually. In this regard, the biomedical engineers have engaged themselves in the creation of the biosensors that will eventually interact with prosthetic devices to detect and make use of bioelectric signals for powering the prosthetic device [15]. The processes on traditional manufacturing have been mostly found to be hand-crafted and also need special abilities on the side of the orthopaedist to prepare a quality product. The morphology acquisition is considered to be not a clean process with the utilisation of the plaster to make the mould. However, the manufacturing process has always created a discomfort among the patients while it has been found that the final product has produced a blistering effect on the skin of the patients. RPT and AMT possess an immense potential to improve the designing process of the orthotic and prosthetic products even also the manufacturing process associated with it. The utilisation of RPT within the orthoprosthetic industry has been considered to be a productive change that has eventually offered important benefits. Therefore, the function of biomedical engineering is not possible alone until a technology is considered.

The main aim is to enhance the overall reconstruction process through "3D analtomical models along with the biomedical products. In this aspect, it can be further stated that production of devices within biomedical engineering strengthens with the potential of RPT and AMT. The CAD followed by the facilitation of the design through RPT and custom-fit prosthetic and orthotic products have been prepared within biomedical engineering with the utilisation of materials, virtual testing and others [15]. TB is a public health issue according to the World Health Organisation (WHO) as the disease has been spreading within half quarter of the population within the world. There are some diagnostic techniques which include TB culture test, "Sputum acid-fast bacillus" and others that have certain limitations.

The disadvantage of the TB test is that it takes much time to produce effective results and the time limit is found to be around 4 weeks. In such a grave scenario, there is a dire requirement for some cost-effective diagnostic tests [15]. One of the important applications of biomedical engineering revolves around offering invention through the assistance of innovative diagnostic tests for various diseases. It is true that LC-MS has produced the desired results and has been successful for the classification of the various types of TB. However, the recognition of the biomarker is more helpful within the blood to identify the normal and abnormal sign of the disease as found while treating the people during the TB pandemic.

The healthcare industry is one of the fastest growing industries and it has implemented industry 4.0 to reduce the cost and time and obviously get better solutions. From the above study, it has been seen that previous and traditional methods of detection and process of medical treatment can detect the different diseases with proper and manual medical tests. In modern days, Industry 4.0 has an excellent positive impact on detecting and controlling the disease as well [16]. From this research study, It has been seen that the designs of modern and advanced medical equipment helped to improve health outcomes with accuracy. There are many differences between bioengineering and biomedical engineering that promotes various practices of engineering segment and it also has been applied to different kinds of biological systems including healthcare, agriculture, as well as pharmaceuticals

This study has applied "additive manufacturing technologies" (AMT), and "3D printing technologies to get the better outcomes from the research study and it has been seen that

Biomedical engineering increased the utilization of FDM to prepare facial prosthesis, hand prostheses, limb orthoses, and many more [17]. On the other hand, the development of RPT has involved biomedical engineering to meet the essential requirements of individuals. accordingly, the rates

of adaptability in the biomedical engineering process are more to gain the efficient quickly and idea on the anatomical shapes and biological structure of the patients.

CONCLUSION

This study is based on Industry 4.0 and healthcare with the biomedical engineering process. From this study, it has been seen that previous process detections and the process of medical treatment of different diseases are possible through Industry 4.0 in the healthcare industry. The connection between healthcare and industry 4.0 has originated by the process of understanding and industry 4.0 implementation in a particular industry. Healthcare industry has been benefitting from the new technologies.This study has also discussed the AI technology that helps to promote the biomedical sector in a modern way. This study also focused on the stem cell therapies that are capable of transforming medicine by enabling the regeneration of disease and immature tissues. On the other hand, it also injures the tissues and assists in curing certain intractable diseases of humans such as diabetes, muscular dystrophy, neurodegeneration" and many more. This study also highlights the application process of implementing industry 4.0 in the healthcare system. In this study, it has been seen that cloud infrastructure allows for the secure handling process of large data. Accordingly, IoT revolves around establishing communication at anytime and anywhere by focusing on digital identification systems with updated machine-to-machine learning methods. The utilized objects in the IoT encompass certain understandings and also try to have connotations that are associated with Radio-frequency identification (RFID) and "Wireless Sensor Networks" (WSNs) to better understand power consumption, strength, and capabilities.

RECOMMENDATION

- Medical sector needs to implement industry 4.0 which helps to improve the patterns of treatment efficiently
- Medical industry should use new technologies that assist individuals to gets better facilities and care for the welfare of the patients

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