Healthcare Services Innovations based on the state of the art Technology Trend Industry 4.0

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***Abstract*—**The contextual compendium analysis presented in this paper focuses on the Industry 4.0 and healthcare services innovation that relate to it. The appraisal discerns the specific components of Industry 4.0 and their related innovations or contribution in the healthcare industry. The first component, Cyber-physical systems, has led to Medical Cyber-physical systems applied in different circumstance to improve the efficiency of service provision. The second component, Internet of Things, has brought with it expanded networks, biosensors, smart pharmaceuticals, and other artificial organs. The final component has inspired the integrated of Natural Language Processing model as a calm-system operating in the background to complete a host of the process that improves diagnoses among other service provision and assistance functions. Additionally, the paper discusses Cognitive Computing, mHealth, and eHealth as emerging medical fields that can benefit from Industry 4.0.

Keywords—Industry 4.0, Internet of Things, Healthcare Industry, Scalability of Industry 4.0, mHealth, eHealth, cyber-physical systems, medical cyber-physical system, medical factories

I. INTRODUCTION

Industry 4.0 is the modern-day equivalent of the industrial revolutions and campaigns that the ancient industrial revolution and the consequential human advancements, commonly known as civilization. Contemporary civilization is as complex as the technologies it relies upon, and its impacts on human development continue to prove critical. Healthcare, like the other service industries, is likely to benefit from the implementation and integration of Industry 4.0 concepts and technologies. Of the many endless possibilities, Industry 4.0 will facilitate the modular structuring of health care models and as such will play a critical role in the actualization of distributed patient care models [1]. Among the many issues facing healthcare today, hospital-based care remains the key challenge to access to health care, although the advent of Industry 4.0 promises to end the gloom and doom that has been associated with this care model.

Without divulging into its history, Industry 4.0 integrates digital technologies, the internet (connectivity) with the conventional industry practices and models to deliver products and services in more efficient ways [1]. In a broad sense, Industry 4.0 encompasses network communication technologies such as machine to machine (M2M) and business to business (B2B) against a backdrop of other advanced information and communication technologies.

II. COMPONENTS OF INDUSTRY 4.0

Figure 1 illustrates some of the key components of Industry 4.0.

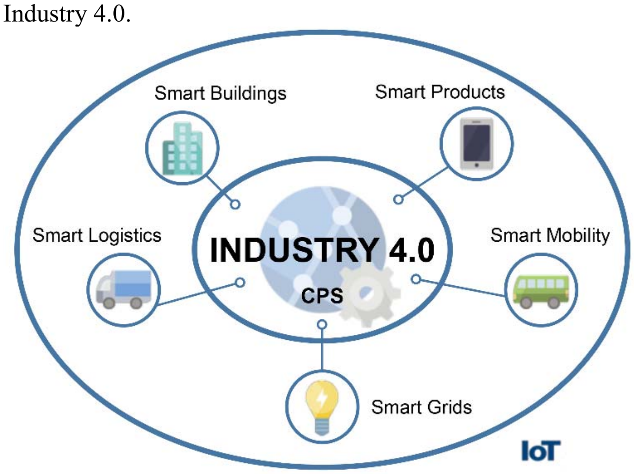

Figure 1: Visualization of Industry 4.0 Components (Source [31]).

The components in Figure 1 are categorized into cyber-physical systems, internet of things, and smart factories.

A. Cyber-Physical Systems (CPS)

The cyber-physical systems consist of sensors, robots, and three-dimensional printers as elements relevant to the healthcare industry. Lee defines CPS as an amalgamation of physical and computational processes in the context of computing [2]. Ideally, integrated computers and monitors over the network execute control commands for the physical processes, and the model of the system entails feedback loops in which physical and computational processes interact [Figure 1]. Most current exploratory implementation of CPS involves the inclusion of socio-economic factors into the framework following the postulation that Data and Services and the Internet of Things interlink the virtual and physical world so that both social and economic aspects in the physical world deserves an integration in the virtual world as CPS represents [2]. In the health sector, the application of CPS is feasible for Body Area Network connections and sensors deployed in Smart Pharmaceutical apps, especially those meant for data collation and aggregation in disease management platforms. Such applications can have auto-regulatory feedbacks, or they can implement measures of

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obtaining such feedbacks using smartphone devices among other accessories.

B. Internet of Things (IoT)

The impact of IoT in healthcare service provision, especially in assisted living subsector is nothing less than revolutionary. Industry 4.0 envisages a Hyper-Connected Society, a concept in which Internet of Everything evolves from the Internet of Things, Services, and People (IoT, IOS, and IoP) [3]. Arguably, IoE as a construct will serve as a value addition tool, and its application will instigate growth and result in prosperity leveraged from the use of digital technologies. The distinguishability of IoT and IoS in Industry 4.0 is suggestive of its objective to virtualize physical processes and translate them into services. IoT is extensive and inclusive of many interconnected devices as Figure 2 illustrates.

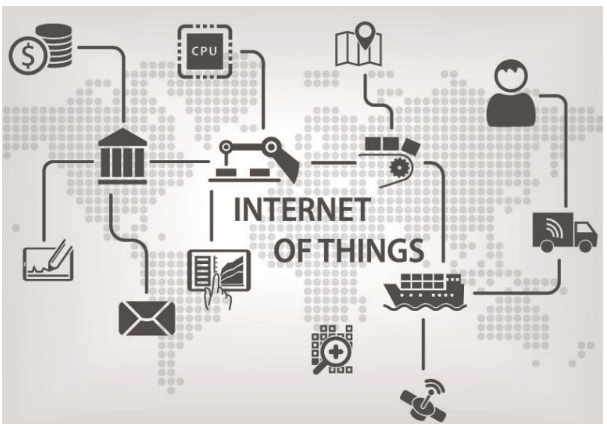

Figure 2: An Illustration of IoT (Source [32])

Nonetheless, concepts such as biosensors, smart pharmaceutical, and artificial organs that were related to the realms of science fiction a few decades ago are a reality [4]. Based on the actualization of such technologies, different digital agenda have initiated various health projects, especially electronic based ones with the objective of grouping health services and streamlining them to take advantage of the infrastructure and devices with the IoT. In specific, several eHealth projects are currently under-development, and upon completion, they will empower both the health workers and patients. Such systems will also provide platforms for linking devices and technologies for the delivery of optimized and personalized health services. The opportunities are endless, and it's paramount to investigate and ascertain the impact of the IoT in medicine with a specific focus on fifth generation network and its possible technological contribution to service delivery.

C. Smart Factory

The concept of Smart Factory is the core of Industry 4.0 because its tenets include context-awareness and ability to automate tasks and assist people in achieving assigned task goals [5]. The operational and technical construct of smart factory involves a calm-system working in the background. It is the stealth system that collates and considers context information such as the coordinates and sizes of an object. It is imperative to note that task completions are based on information retrieved from both the physical and virtual world. The virtual world information most consists of electronic data including diagrams and models for simulations.

In the healthcare industry, distributed care systems exemplify smart factories. A viable example is the use of hospital information system to gather information on a patient, particularly in readmission cases. In this case, the calm-system can a recommender algorithm that deploys deep learning algorithm such as Decision Trees to classify patients and establish predisposing factors for given maladies [6]. However, in the context of "smart factories," some real time physical information on like the position of the patient limits the application of such systems. It is undeniable that a gap exists between "medical factories" and their "smartness" because most facilities are yet to achieve the synergies between the two aspects. However, the inclusion of socio-economic factors may improve this situation, bridge the gap, and improve the efficiency of smart factories in the healthcare industry.

Table 1 summarizes the importance of Industry 4.0 to these three sectors. The table identify the key contributions that Industry 4.0 has made in health, education, and business.

Table 1: Literature on the impacts of Industry 4.0 on Health, Education, and Business

Application Field	Articles/Authors	Main Contribution
Business	Niu, Wang and Zhang [16], Raman, Rachamadugu and Talbot [17], Tupa, Simota and Steiner [18], Zhong, Xu, Klotz and Newman [19], Barreto, Amaral and Pereira [20], Witkowski [21], and Shim, Park and Choi [22].	• Risk Management • Production Planning and scheduling • Automation of Manufacturing processes • Artificial intelligence and robotic automation • Customer satisfaction measurement • Complex logistic programming and planning • Business intelligence • Optimization of customer relationship and streamlining of market. • Intelligence in management of production resources • Improved inventory management techniques • Cloud and IoT business processes. • Development of sustainable business models
Education	Fernández-Miranda, Marcos, Peralta and Aguayo [23], Benešová and Tupa [24], Karre, Hammer,	• Benchmarking • Big data and data mining on replicable platforms • Inspiring practical learning environment • Human resource management

	Kleindienst and Ramsauer, [25]	• Education 4.0 including online blackboards and distance learning • Gamification • Virtual learning environments through video conferences among other technologies
Health	Elhoseny, Abdelaziz, Salama, Riad, Muhammad and Sangaiah [26], Jurenoks and Jokićb [27], Sun *et al* [28], Elrod and Fortenberry [29], and Padfield [30]	• Cost reduction implications • Wireless sensor networks for improved monitoring • Electronic health record systems • Mobile health applications • Improve diagnosis and patient management practices • Support of personalized medicine prospects

III. Scalability of Industry 4.0

Industry 4.0 is wide and encompassing with its applications becoming integral parts of the different production, manufacturing, and service provision across different industries. If the healthcare industry can achieve the modular structure and operate as a Smart Factory, then it must have a CPS that monitors all the physical processes, virtualizes the physical world, and uses algorithms in its decentralized decision-making functionality [6]. In the conceptualized hospital setting, the CPS engages in real communication and corporation with each and hospital stuff over the IoT in real time. Through the IoS, doctors, nurses, and other hospital staff offer and utilize internal and cross-hospital services that of grave importance to value chain.

The organization of value chain has become an important practice in health care because of the pressure to minimize budgets while simultaneously improving effectiveness and efficiency of service provision. Of the most commonly encountered challenges that value chain management remedies, counterfeit drugs, and unnoticed drug expiry are the most economically damaging ones. Approximately one million deaths globally are ascribed to intoxication from counterfeit drugs, and as such the quality of care is also poor. Furthermore, lack of expiry controls for drugs and medical consumables has also proven lethal with hospitals losing billions worth of disposed of products. The healthcare industry also grapples with the patient flow (queues and waiting time) as part of its value chain [6]. Regarding these aspects, the industry can benefit from the implementation of Industry 4.0 techs, and the feasibility relies on the structuring of the hospitals using modular models. More importantly, the implementation of such technologies will facilitate the process of transition from hospital-based to patient-centered care that streamlines the services and aspects of care around the patient.

The focus and aggregation of services and care elements around the patient is a strategy that benefits the patient because different departments, roles, and responsibilities provide support geared towards optimum patient health outcome. The rapidity of technological development has led to the actualization of Medical CPS which intends to improve patient care through personalized treatment-based sensors and patient modeling. However, MCPS has brought with it more challenges because it is quite complex compared to conventional medical systems [7]. Addressing the developmental challenges require solutions for new designs alongside differentiated composition and techniques of verification and validity. Consequently, the opportunities associated future medical devices are dependent on the new techniques for MCPS implementation [7]. In future, MCPS will include patient-controlled analgesia, smart alarm systems with effective models for vital monitoring, and reached automation actuation point.

IV. Emerging Healthcare Applications

MCPS among other components of Industry 4.0 is currently applied in different medical fields. For instance, improved functionalities in embedded systems have benefited the robotic surgery because of the real-time data processing involving high-resolution imagery and instant haptic feedback. The other field that has benefited from MCPS is proton treatment therapy, which also requires real-time processing of images [7]. Besides the improving software functionalities, most of the model medical devices have network interfaces and with such functionalities come the ability to join distributed networks and ensure effective patient monitoring activities.

A. Cognitive Computing

With the advent of Big Data concepts and systems that can handle huge datasets came computational requirements and the subsequent development of techniques for analyzing the data [8]. Patient data are fast accumulating and with the development of secure databases, cognitive systems can help in both analytics and predictive prospects. Cognitive computing entails algorithms that self-learn data using deep learning, machine learning, and pattern recognition algorithms [9].

Cognitive computing is an example of how medical facilities can achieve the "smart factory" status. The algorithms are part of the calm-system working on the background [10]. The algorithms are either content-based or collaborative filtering in nature. Given the quality of the medical data, most cognitive systems pursue collaborative filtering algorithms with include both model-based and memory-based models [11]. Both groups of models form the framework some of the existing health recommender systems. An example of a model-based algorithm that can serve as a calm-system is the k-nearest neighbor (kNN) which is a classifier algorithm that recognizes patterns [12]. Suppose the implementation of the algorithm targets improving diagnosis of a given condition, then the system process text documents from a medical database to retrieve and aggregate the most relevant information. In application, the algorithm requires an instance description $\alpha \in \mathrm{A}$ with A being the instance space and a fixed set of categories $C = \{c_1, c_2, ..., c_n\}$. Suppose A is a database containing different tests and observations for positive and negative results on different strains of bacteria and C is a set of the bacteria then the objective of the kNN algorithm is retrieved test results for a specific bacterium. The mathematical notation of the scenario as shown [12].

$$\alpha : c(\alpha) \in C \tag{1}$$

It is imperative to note that natural language processing has emerged to be far much more useful than conventional classifiers such as the kNN. Natural language processing mainly uses deep learning algorithms such as Naïve, Bayesian, Neural Networks, and Support Vector Machines among others. Cognitive computing, when implemented in NLP framework using the most efficient algorithm, can improve diagnosis alongside other services in the medical service industry. Furthermore, the emergence of cloud-based computing capabilities and artificial intelligence platforms, such as that of IBM Watson, demonstrate the future of cognitive computing in health care. Of the many components and concepts of Industry 4.0, the inclusion of cognitive computing techniques as part of the calm-system is revolutionary and will prove critical in bridging the gap between Industry 4.0 technologies and human language.

B. *eHealth and mHealth*

Leveraging the Big Data to improve services in the Healthcare industry has its data storage and availability demands. After the completion of the Human Genome project, the launch of electronic health records concept, and the successful initiation of the Internet of Things, it becomes apparent that facts per decision were beyond the human cognitive capacity. Besides building the cognitive systems and integrating them appropriately, it became equally important to devise methods of storing the Big Data, and eHealth plants have proven quite effective.

eHealth is the integration of information and communication technologies in health provision. In any given facility, it collates the process from admission, drug administration, to financial services, especially preparation of statement for insurance coverage [13]. Industry 4.0 will advance the digital equipment used in eHealth because the current eHealth platforms have gaps that may require more complex and advanced solutions. With the concepts and technologies of Industry 4.0, eHealth will become more dynamic with improved data protection and expanded networking capabilities. Moreover, introduction of concepts such teleconsulting and data protection charters will improve the performance of both eHealth and healthcare industry.

Regarding IoT and the rapid growth in the number of smart devices, mobile health recognized with its mHealth moniker, will gain popularity and play a revolutionary role in the industry. The concept of mHealth is an example of the influence of Industry 4.0 because it seeks to implement machine learning concepts in the advanced environment [13]. It is a convergence of Big Data and IoT for improved financial services. The framework mHealthDroid is an example of the plausible implementation of Big Data analytics in the context of IoT. Similar systems, including mDurnace, qualify as the beneficiaries of the advancements that come with Industry 4.0 [14,15]. In fact, moving forward, some health-based applications and systems will increase not just because of Industry 4.0 but also other internet-based digital trends that are using effective and efficient technologies. An example is some possible use queuing systems to reduce hospital waiting time.

Industry 4.0 and its concepts and technologies were first created with the aim of enhancing the manufacturing industry in a technological sense of it although its rapid acceptance has led to its equally expansive adoption in different sectors. Of the many sectors that are already benefiting from Industry 4.0, health, business, and education sectors are the beneficiaries that are likely to push its boundaries and test its concepts. A review of critical literature on this thematic or sectorial areas have revealed that Industry 4.0 is an obscure field in education based on the number of research articles exploring the possibility of Education 4.0. The integration of Industry 4.0 in education and business are discussed as follows.

C. *Business*

Business is wide and encompassing although it is one of the sectors or activities that involves an inter-web of activities that can easily benefit from automation. As Figure 3, illustrates from a broader sense, concepts and technologies related to intelligent management, cloud manufacturing, and IoT based manufacturing have been inspired and continues to improve production efficiency in the manufacturing sector [16]. At first, Industry 4.0 was thought of a disruptive technology but has since proven otherwise. Currently, most industries are in pursuit of "smart factory" concept with automation prioritized across different sectors. For instance, in most manufacturing plants, Industry 4.0 based calm-processes are used in scheduling and planning various aspects of production [16]. Figure 3 demonstrate some of the Proper scheduling allows for proper product quality control besides increasing inventory turnover and improving critical inventory management aspects. The influence of Industry 4.0 has also extended to the engineering and production of smarter robotics for better in-plant performance and faster delivery.

However, most of the recent contribution of Industry 4.0 to businesses is evident in cloud-based platforms that utilizes advanced networking platforms to deliver services, including cloud manufacturing [17]. Cloud technology has brought with more advantage to different aspect of business management including data safety. The elevated level of digitization has introduced flexibility in business model and have made the product and service deliver personal and up-close. Despite the ongoing debate on the consequence of automation on unemployment, firms have saved up to 4% of their operational costs while guaranteeing higher efficiency levels.

Figure 3: Industry 4.0 Applications for Business Integration (Source [33]).

In specific, the proliferation of enterprise resources planning (ERP) systems are examples of the revolutionary impacts of Industry 4.0 on businesses. Besides efficient management approaches, most businesses have installed integrated systems for planning and asset utilization. More importantly, businesses are embracing the power of information especially those acquired from predictive algorithms such as sentimental analysis and product recommending system that allow them implement personalized promotion strategy.

In addition to the intelligence, business use cloud-based platforms for collaboration, communication, and project management so that value chain management becomes easier and effective with adoption of Industry 4.0 technologies. Regarding pursuit of intelligent inventory tracking, Industry 4.0 will delivery tracing devise that will prove important in risks management from the perspective of inventories or products dispatched to suppliers [18]. Even though most of these concepts are still new and underutilized, global businesses with penetration and resources are also benefiting from Industry 4.0. A good example is the impact that Industry 4.0 have had on the advances in export and import since the conception of the drop shipping concept. Giants such as Amazon and Alibaba have been round long enough, but they had to grapple with longer delivery days and cumbersome customer-destination search. However, drop shipping alongside effective spatial data mapping services have simplified import and export to an extent that purchase of products are localized on a global scale [19]. Items that were delivered in over 60 workings can now be received in under 14 working days.

These advancements are not only opening new opportunities but also equipment businesses and positioning them advantageously for competition both at local and international levels. Of concern with such exposure are risks, financial or otherwise, although the continued development into security aspects of Industry 4.0 is guaranteeing a better future. Regarding the competition, it has emerged that digitization of existing portfolio and opportunities to offer new products and services in high-tech cutting environment is rapidly expanding the market share for all businesses. Hence as business continues to integrate the low-cost yet efficient Industry 4.0, the impacts of competition on their financial performance diminishes [20]. With manufacturing execution systems and product lifecycle management, it is increasingly becoming easy to integrate solutions that minimizes business risks while exposing the business to larger proportion of the target audience. Also, value creation has become easier because businesses have tools for augmenting product digitally. Most importantly, Industry 4.0 envisages to promote quality and efficiency in various stages of the lifecycle of a product [21]. The systems also have data collation and aggregation services that can be leveraged to offer better services to the customers, and for this reason that businesses develop and modify their models centering them around target clients. From a business stance, such strategies improve customer loyalty that can translate to higher margins with proper execution plans [22]. Given that Industry 4.0 will be introducing innovative ideas, it will constant face criticism although the higher rates of modern technology acceptance will continue to disentangle such doubts.

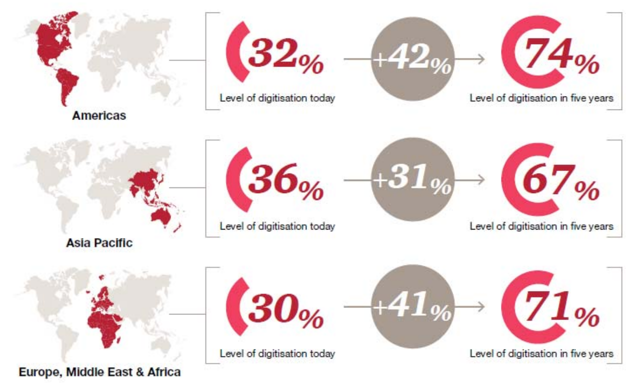

Figure 4: Current Digitization Status Globally (Source: [[34]).

As Figure 4 illustrates, 32% of US based companies are digitized although the number will increase to 74% in five years. Similarly, Asia Pacific, and Europe, Middle East & Africa have 36% and 30% digitized companies while the number will increase to 67% and 71% respectively after five years [31]. The projections show a likely increase in demand due to digitization.

D. Education

The intersection of Industry 4.0 and education remains obscure from a research perspective because there are quite enough evidence earmarking the currently undergoing developments. For example, online blackboards and distance learning programs are becoming more popular. Some of the prestigious universities have joined in and offers classes through webinars and other video services. Despite the lack of attention that "Education 4.0" is not receiving, it remains one of the contentious subject of interest because the success of Industry 4.0 is dependent on higher levels of education. Arguably, education and Industry 4.0 are mutually inclusive although the distinction remains ambiguous and their integration remains elusive. For instance, Fernández-Miranda et al. [23] acknowledges that it is challenging for higher instructions of learning to integrate Industry 4.0 in current curriculum. As such, experts in different fields are working with scholars on different benchmarking projects to introduce from a practical point of view all concepts related to the new wave of revolution [24]. An example is the proliferation of data science training services such as Data Camp that aims at teaching and training concepts related to Big Data and data mining algorithms. Such platforms are educative and uses some of the advances associated with Industry 4.0. The academic community has also responded to the demands of the industry and higher learning institutions have created curricula and other learning resources to improve expert profiles on informatics, PLC programming, and robotic programming [25]. Both "Education 4.0" and Industry 4.0 are benefiting from each other because with every increasing demand for manufacturing, production, and automation experts comes an opportunity for the academic community to explore industrial concepts and prototypes at research stage. Furthermore, Industry 4.0 has made major contributions to research and development departments leading to inoculation of ideas and promoting creativity [25].

Regarding education learning devices and equipment, Industry 4.0 have led to remarkable contributions, especially in developing assistive learning devices. Although some of the assistive devices are considered health issues such as prosthetic, their use in education render them educative tools and to this existent Industry 4.0 has made major transformation. For instance, with the planning and scheduling software and systems, the process of manufacturing prosthetic has become so high tech that finite analysis methods have become so effective in accurately measuring pressure distribution in joints and other pressure sensitive sections. With such increased accuracy of measurements, students using such assistive devices find them more comfortable and as such they are more likely to register higher scores. As for other assistive devices, machine learning and deep learning platforms such as Watson have made it easier to implement audio learning platforms and improve language mastery and command. Additionally, white boards can also be considered as important innovations from Industry 4.0. Finally, given the pace of personal computer acquisition, soon it will be possible to attend live class sessions at the comfort of a living room. The premises of the such projects are IoT, improved wide area connectivity among other technologies associated with Industry 4.0.

V. Conclusion

The research paper has asserted that Industry 4.0 have had greater impacts in health, education, and business sectors. Business application of Industry 4.0 have been widely researched while application the same technology is obscure. Besides, there is a lack of expertise and manpower to implement these systems. However, the benefits of the industry 4.0 can outweigh all the issues for numerous production facilities. In health sector, many areas can be improved dramatically, and supply chain management can also be heavily controlled as the data is accessible at every level of manufacturing, production and delivery process.

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References

[1] H. Lasi, P. Fettke, K. Hans-Georg, F. Thomas, and M. Hoffmann, "Industry 4.0," *Business & Information Systems Engineering* vol. 6, no. 4, pp. 239-242, 2014.

[2] E. Lee, "Cyber-Physical Systems: Design Challenges*,"* In *11th IEEE Symposium on Object and Component-Oriented Real-Time Distributed Computing (ISORC), pp 363–369.*

[3] M. Hermann, P. Tobias, and O. Boris, "Design principles for industry 4.0 scenarios," In *System Sciences (HICSS), 2016 49th Hawaii International Conference IEEE*, pp. 3928-3937, 2016.

[4] D. V. Dimitrov, "Medical internet of things and big data in healthcare," *Healthcare informatics research* vol. 22, no. 3, pp. 156-163, 2016.

[5] P. Zawadzki, and Z. Krzysztof, "Smart product design and production control for effective mass customization in the Industry 4.0 concept," *Management and Production Engineering Review* vol. 7, no. 3, pp. 105-112, 2016.

[6] B. Silverman, N. Hanrahan, G. Bharathy, K. Gordon and D. Johnson, "A systems approach to healthcare: Agent-based modeling, community mental health, and population well-being," *Artificial Intelligence in Medicine*, vol. 63, no. 2, pp. 61-71, 2015.

[7] R. Rajkumar, D. Niz and M. Klein, "Medical Cyber-Physical Systems," in *Cyber-physical systems*, 1st ed., Boston: Addison-Wesley Professional, 2016, pp. 3-52.

[8] J. Yan, Y. Meng, L. Lu and L. Li, "Industrial Big Data in an Industry 4.0 Environment: Challenges, Schemes, and Applications for Predictive Maintenance", *IEEE Access*, vol. 5, pp. 23484-23491, 2017.

[9] M. Wiesner and D. Pfeifer, "Health Recommender Systems: Concepts, Requirements, Technical Basics and Challenges," *International Journal of Environmental Research and Public Health*, vol. 11, no. 3, 2014, pp. 2580-2607.

[10] S. Nirenburg and M. McShane. "Natural language processing." *The Oxford Handbook of Cognitive Science,* 2016.

[11] M. Chen, J. Yang, Y. Hao, S. Mao, and K. Hwang, "A 5G cognitive system for healthcare," *Big Data and Cognitive Computing* vol. 1, no. 1, 2017.

[12] M. Muja and DG. Lowe, "Scalable nearest neighbor algorithms for high dimensional data," *IEEE transactions on pattern analysis and machine intelligence* vol. 36, no. 11, pp. 2227-2240, 2014.

[13] O. Banos, J. Moral-Munoz, I. Diaz-Reyes, M. Arroyo-Morales, M. Damas, E. Herrera-Viedma, C. Hong, S. Lee, H. Pomares, I. Rojas and C. Villalonga, "mDurance: A Novel Mobile Health System to Support Trunk Endurance Assessment," *Sensors*, vol. 15, no. 6, pp. 13159-13183, 2015.

[14] H. Jung and K. Chung, "Knowledge-based dietary nutrition recommendation for obese management," *Information Technology and Management* vol. 17, no. 1, pp. 29-42, 2016.
[15] A. Kumar, "Cyber-Physical Systems (CPSs) – Opportunities and Challenges for Improving Cyber Security," *International Journal of Computer Applications*, vol. 137, no. 14, pp. 19-27, 2016.
[16] TZ. Niu, , X. Wang and H. Zhang, Clonal selection algorithm for parallel machine scheduling with setup time, *J. SE Univ. (Nat. Sci. Ed.*, vol. 42, pp. 163–167, 2012.
[17] N. Raman, R. V. Rachamadugu and F. B. Talbot, Real-time scheduling of an automated manufacturing center, *Eur. J. Oper. Res,* vol. 40, pp. 222–242, 2009.
[18] J. Tupa, J. Simota and F. Steiner, "Aspects of Risk Management Implementation for Industry 4.0", *Procedia Manufacturing*, vol. 11, pp. 1223-1230, 2017.
[19] R. Zhong, X. Xu, E. Klotz and S. Newman, "Intelligent Manufacturing in the Context of Industry 4.0: A Review", *Engineering*, vol. 3, no. 5, pp. 616-630, 2017.
[20] L. Barreto, A. Amaral and T. Pereira, "Industry 4.0 implications in logistics: an overview", *Procedia Manufacturing*, vol. 13, pp. 1245-1252, 2017.
[21] K. Witkowski, "Internet of Things, Big Data, Industry 4.0 – Innovative Solutions in Logistics and Supply Chains Management", *Procedia Engineering*, vol. 182, pp. 763-769, 2017.
[22] S. Shim, K. Park and S. Choi, "Innovative Production Scheduling with Customer Satisfaction Based Measurement for the Sustainability of Manufacturing Firms", *Sustainability*, vol. 9, no. 12, p. 2249, 2017.
[23] S. Fernández-Miranda, M. Marcos, M. Peralta and F. Aguayo, "The challenge of integrating Industry 4.0 in the degree of Mechanical Engineering", *Procedia Manufacturing*, vol. 13, pp. 1229-1236, 2017.
[24] A. Benešová and J. Tupa, "Requirements for Education and Qualification of People in Industry 4.0", *Procedia Manufacturing*, vol. 11, pp. 2195-2202, 2017.
[25] H. Karre, M. Hammer, M. Kleindienst and C. Ramsauer, "Transition towards an Industry 4.0 State of the LeanLab at Graz University of Technology", *Procedia Manufacturing*, vol. 9, pp. 206-213, 2017.
[26] M. Elhoseny, A. Abdelaziz, A. Salama, A. Riad, K. Muhammad and A. Sangaiah, "A hybrid model of Internet of Things and cloud computing to manage big data in health services applications", *Future Generation Computer Systems*, 2018.
[27] A. Jurenoks and D. Jokićb, "Coordinator Role Mobility Method for Increasing the Life Expectancy of Wireless Sensor Networks", *Applied Computer Systems*, vol. 21, no. 1, 2017.
[28] J. Sun *et al*, "Smart services for enhancing personal competence in industrie 4.0 digital factory," *LogForum,* vol. 14, *(1),* 2018. Available: https://search.proquest.com/docview/1978917514?accountid=145382. DOI: http://dx.doi.org/10.17270/J.LOG.2018.239.
[29] J. K. Elrod and Fortenberry,John L.,,Jr, "Peering beyond the walls of healthcare institutions: a catalyst for innovation," *BMC Health Services Research,* vol. 17, 2017. Available: https://search.proquest.com/docview/1925246709?accountid=145382. DOI: http://dx.doi.org/10.1186/s12913-017-2342-9.
[30] J. R. Padfield, "A Study of Innovation Processes used in the United States Healthcare System." Order No. 3605045, Purdue University, Ann Arbor, 2013.
[31] Industry 4.0, Industrial Internet of Things - What's the difference and what are the benefits?", *IoT ONE Community*, 2018. [Online]. Available: http://community.iotone.com/t/industry-4-0-industrial-internet-of-things-whats-the-difference-and-what-are-the-benefits/35. [Accessed: 15- Apr- 2018].
[32] A. Robinson, "Industrial Internet of Things in Manufacturing Applied", 2016. [Online]. Available: http://cerasis.com/2016/03/18/industrial-internet-of-things/.
[33] A. Melanson, "Robotics and Industry 4.0 - Aethon Blog", 2015. [Online]. Available: http://www.aethon.com/industry-4-0-means-manufacturers/.
[34]"Industry 4.0". [Online]. Available: https://www.pwc.com/gx/en/industries/industry-4.0.htm