Intelligent Decision Support System for Precision Medicine (IDSS 4 PM)

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Abstract. Availability of healthcare big data and limited human cognitive to decide timely, from one hand and unsuccessful business model of traditional Medical Decision Making(MDM), on the other hand, have challenged the healthcare/medicine landscape to pioneer Precision Medicine (PM). This study aims to propose the conceptual framework of the Intelligent Decision Support system for Precision Medicine (IDSS4 PM), by highlighting the fundamental role of key technologies.

Keywords: Intelligent Decision Support System, Precision Medicine, Medical Decision Making, Business Analytics, Cognitive Computing. Big Data.

1 Introduction

The consequences of the failed business model of traditional Medical Decision Making (MDM) including poor quality of healthcare service, cost of over-treatment and less effective medicine have been a serious challenge for nations. Moreover, the evolution of digital transformation and advancement in technologies cautiously leading to providing the foundation to transfer the empirical medicine to "Precision Medicine" (PM). Where, "one -size –fits- all" replace by "Patient-Like-Me" to release the right medicine, for the right patient, at the right dose, and at the right time [24].

The development of such a framework ,relies on technologies such as Business Analytics (BA) and Cognitive Computing (CC) [2]. "Google DeepMind "and "IBM Watson" are two examples of CC applications that have improved medical decision making via analyzing insight the structured and unstructured data (e.g., clinical notes, reports), and for choosing the best treatment pathway [4, 21]**.**

This study intends to propose a framework from the domain of Intelligent Decision Support Systems (IDSSs) and to define it for PM. Where BA and CC are crucial technologies to perform over individual patient data.

2 Theoretical Foundation- Simon's Model of Decision-Making

The "Intelligence-Design-Choice" model, which was identified by Simon, has been applicable as the most complete framework in decision-making. Later he added the "Implementation" phase.

"Intelligence" is the first step for scanning the environment to identify problems or opportunities, this phase may include the result of the implementation phase [25]. Furthermore, the "Design" phase is about inventing, developing, and analyzing possible courses of actions [19]· In other words, conceptualizing the problem in this phase, leads to modeling where different scenarios are designed, validate, and tested. [7]**.** Besides**,** in "Choice", there is the matter of evaluating those solutions and choosing among them. [28].Moreover, this phase, which is a decision-focused phase, identifies whether the result would be normative or satisfy [8]**.**These steps are repeated iteratively with many feedback loops until the final choice has been implemented [11]**.**

2 Intelligent Decision Support Systems (IDSSs)

The general architectures of an Intelligent Decision Support System (IDSS) includes input (e.g., data, knowledge, advice, algorithms, or models), processing (e.g., forecasting, recommendations or a feedback loop) and output including the outcome of this process that can be considered as the new input for the new analysis [23]**.** For instance, Expert Systems (ES) are a type of intelligent systems, which use knowledge base input and stores rules. Moreover, IDSSs use data mining techniques to extract insight from data in the form of reports recommendation and prediction [1, 9, 12, 20, 27]**.** Besides, IDSS demonstrates intelligent behavior such as self-learning from experience, quick and successful response to the new situation, knowledge processing, operating functions ,generating value, reasoning for problem-solving, and generating answer according to the incomplete input variables [17, 23]**.**

3 Precision Medicine; An Emerging Approach in Medical Decision Making

The traditional practice of MDM, which has been driven by trial and error and physician's judgement, generalizes the solution based on empirical evidence; treats all patients with similar symptoms in the same way [21]**.**Consequently, the business model of "One-Size-Fits-All" [21] has caused the patient to become the victim of an ineffective drug or deal with side effects or poor outcomes. Where, answering the questions such as why does a drug work for some patients and be less effective on others? Why does medicine cause side effects on some individuals? needs the medical practice of tailoring each patient as a unique case.

On January 20, 2015, the former president Barack Obama launched "Precision Medicine" that has been a remarkable research opportunity in a new area of medical practice [8]. According to the U.S. National Library of Medicine, "Precision Medicine" is an emerging approach that considers individual differences such as genes, environment, and lifestyle for preventing and treating particular diseases [9]. According to figure 2, PM intends to take into account individual patient's variables in terms of

genetic, lifestyle, and environmental effects in medical decision-making. Additionally, distinguishing patients from other patients with the same symptoms, improving the performance of treatment, minimizing side effects and medical [10].

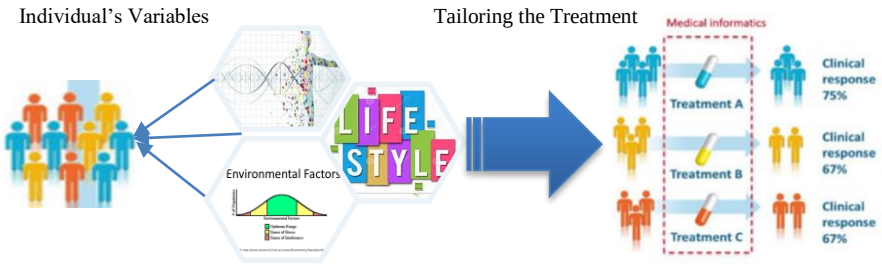

Fig 1. Precision Medicine

4 How Technologies are advancing Precision Medicine?

4.1 Business Analytics

The availability of big data identified the requirement of big analytics. Considering the maturity of BA, the descriptive analytics answers the question of what happened/why it happened, by providing information in the format of reports, dashboards, and data visualizations. Moreover, predictive analytics, which projects techniques such as data mining and text mining, uses the past behavior of data to predict or forecast future opportunities /problems. Finally, the optimal decision is achievable through prescriptive analytics [7].

Although in recent years increasing the volume of diverse data from different resources [24] with different level of complexity has challenged the current model of medical decision making, it has brought new opportunities for health analytics to perform over healthcare big data. As figure 2 shows, descriptive /diagnostic analytics over patient data, helps decision-makers to observe and analyze the situation. For instance, detecting a particular disease. Moreover, distinguishing a person at risk is possible when predictive analytics uses individual patient data to predict behavior[15]. Furthermore, prescriptive analytics**,** adopts the information generated from predictive analytics to perform a proactive decision. In other words, precision medicine is a good example when prescriptive analytics uses individual patent data to propose the best possible medical decision. Besides, finding an unknown disease or treatment is an example of discovery analytics that performs on healthcare data [18].

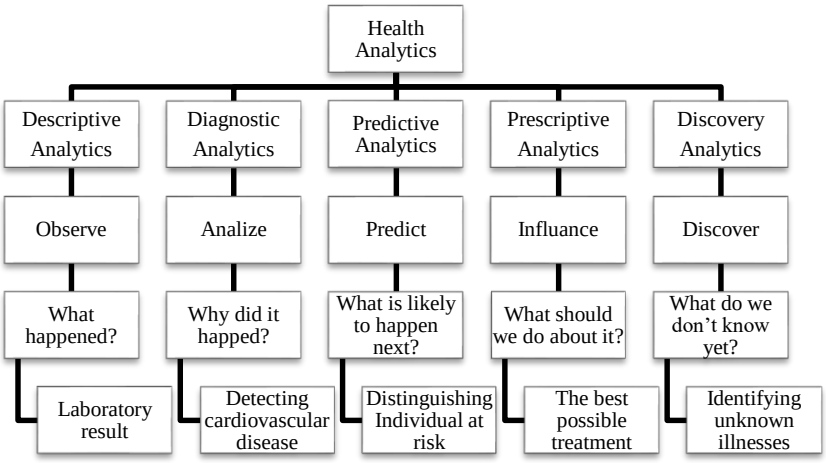

Fig2. Health Analytics, Adapted from [16]

4.1 Cognitive Computing

Cognitive Computing is defined as the computing systems that work via mathematical models to simulate the human cognition process. Therefore, self-learning techniques such as machine learning that uses data mining approaches, are the key feature of this innovative technology [7].

Since healthcare data, carries the characteristics of big data (V6) such as variety (various data format), velocity (the speed of data creation and data flow), value (data is valuable) and variability (data changes), volume (refer to the huge size of data) and veracity (if the quality of data is trustable) [15, 16],thus for decision-making purposes, an advanced computing system which uses machine-learning techniques is vital. Such a system that could facilitate the management of big data [3]. Moreover, the combination of CC and BA are the fit bootstrapped to perform over patients data (genes, environmental and lifestyle) [5] for proposing the most effective outcome in the concept of PM [6].

5 Theory Practice and Discussion

Justifying the IDSS 4 PM by Simon's model in decision-making demonstrates a strong relationship between influential technologies (BA and CC and) and the concept of optimal decision-making. According to table 1, the first two levels of analytics (descriptive/diagnostics and predictive) which focus on knowledge discovery and creating information from data, belong to the "design" phase in Simon's model of decision making. Moreover, since predictive analytics generate algorithms and does

formulation, hence it belongs to the "intelligent" phase. Where, "choice" phase includes activities for searching an appropriate course of actions, prescriptive analytics, adopts techniques such as simulation and sensitivity analysis to propose the best possible decision [7].

Table1. Theory practice and BA

Decision Making Task	Simon's model in decision making				Health analytics			
	Intelligent	Design	Choice	Implementatio	Descriptive	Diagnostics	Predictive	Prescriptive
Searching for data/information	X					X		
Searching for data/information	X	X			X	X		
Generating information/knowledge	X	X			X	X		
Generating alternatives		X					X	
Evaluating alternatives			X					X
Sensitivity analysis			X					X
Searching an appropriate course of actions			X					X
Choosing the best possible action			X					X
Proactive actions				X				X

As we discussed above, there is no clear boundary between design and choice phases. Since decision-makers may need to return frequently from choice phase to design's and generating alternative may be in parallel with evaluating the existing one. Moreover, in normative models of decision-making, to obtain the optimal decision, all the possible alternatives should be generated and examined to prove that the selected result is the best decision. The "design" phase needs activities to conceptualize the problem, design hypothesis, find the relationship between variables, define features, and identify all the possible scenarios. As a result, according to the role and level of each analytics, the boundary between predictive and prescriptive analytics is very narrow. Therefore, based on activities done in the "design" phase, the optimum result is achievable in the "choice" phase, This process is "optimization" and these two phases; "design" and "choice" includes activities that influence this process for obtaining optimal result [22].

6 Characteristics of IDSS 4 PM

Base on the above explanation, IDSS4PM, is a framework that carries major specifications. According to Figure 3, since, the framework deals with data and information, it is a data-driven model. Moreover, because the decision would be

achieved via what-if scenarios with a goal attainment approach and by responding to the new situation, therefore it has an adaptable architecture. Furthermore, IDSS 4 PM, performs based on predictive and prescriptive analytics, hence the result would an optimal decision; we call it a recommender. In addition, the constructive of the framework is based on cognitive computing/ machine learning. Thus, IDSS demonstrates intelligent behavior such as self-learning from experience, knowledge processing, and operating functions (based on probabilistic data)

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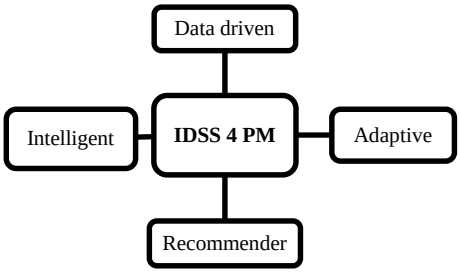

Fig 3. Major features of IDSS 4 PM

7 Conclusion

This paper intended to introduce a conceptual framework of IDSS 4 PM by addressing the influential role of key technologies such as BA and CC. Whereas, less quality of treatment, cost of overtreatment, and ineffective drugs as the major consequences of the unsuccessful business model of old MDM have put pressure on healthcare landscape, availability of healthcare big data and fundamental roles of technologies have tackled the limited human cognitive in timely decision-making. Thus, the transition from “One-Size-Fits-All” to “Patient-Like-Me” has been an advanced step towards precise decision-making in medical practice.

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