# Intelligent Medical Platform for Clinical decision making

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*Abstract—* **The objective of this research is to extend the core technologies of exiting clinical decision support systems (CDSS) infrastructure towards multi-level maintenance of knowledge bases by designing and developing innovative methods of knowledge acquisitions. The new idea is to design and develop evidence and dialogue based clinical decision support system to support diverse knowledge resources (i.e. unstructured text, images, and structured EMR/EHR data) for evolutionary knowledge base with novel technology. We propose dialogue-based Intelligent Medical Platform (IMP) that is a platform to support services on top of the incremental learning based on evolutionary knowledge bases from diverse sources by integrating legacy systems with multiple data formats, supported by clinical standard-inspired big data persistence. The system is fitted out with dialogue environment in the form of text, voice, and image to physicians and patients during treatment, diagnosis and health related recommendations, alerts, coaching, and education. It overcomes the existing systems limitations in terms of evolutionary knowledge base, dialoging ability of interaction, integration with legacy healthcare systems such as hospital information and management systems (HMIS), and handling multimodal data from diverse input sources.**

*Index Terms—* **Decision support, Knowledge Management, Knowledge Representation, Interoperability.**

## I. INTRODUCTION

Intelligent medical technology has vital role in improvement of patient safety and reducing healthcare costs by automating workflows and assisting physicians and other healthcare professionals [1]. Nevertheless of the vast benefits, medical recommendation systems adaptation is still underneath the expectations of medical community. Time pressure, communication gap among patients and physicians, immaturity in knowledge bases, hard usability and interaction with healthcare systems are the main causes for medical errors, physicians' exclusion in everyday practice, and unreliability to evidence-based guidelines [2]. Clinical decision support systems (CDSS) are advantageous to handle many encountered problems and offer patient-centered actionable recommendations to enhance the clinical decisions capabilities in clinical practices and trials. CDSS creates a harmonization path between patients and physicians by providing operative recommendations, alerts, and reminders at the proper time to the right patients [3].

System usability of CDSS systems have investigated and observed that 43% of findings are clearly supported by data for inappropriate interruption, inefficiency, additional work, transparency, and information presentation [4]. Therefore, several barriers constrain the efficiency of CDSS implementation in the real field. The challenges and barriers include limited semantic interoperability in patient data acquisition, modeling and elicitation of medical knowledge, representation and reasoning integration of CDSS in medical workflows, users' interaction with systems, and authenticity of knowledge evidences [5].

The trend of CDSS is directing towards interaction with systems in a human oriented manner using dialogue based communication. It needs integration of questions-answering sessions, actions of user request, and integrating natural language with computer vision in computational linguistics [6]. The barriers of friendly user interaction with system can be resolved with dialoging communication. Additionally, the users' dialogue with physician in form of holographic avatar is highly collaborative than dialogue with mobile or computer device directly [7]. Therefore, existing CDSS lack conversational ability of interaction, constrained to single-turn settings, lack self-evolvable knowledge representations, lack any notion of context while interacting with the user, and have limitations in handling multimodal data from an array of different input sources. Similarly, current dialog systems lack

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incremental knowledge ability to evolve its knowledge accurately through machine learning and human experts. Similarly, one of the barrier of adaptation of CDSS in a practical field, is complex usability of the system for physicians and patients. Therefore, physicians and patients feel encumbrance to utilize a complex system.

The amalgamation of dialogue-based conversational system and CDSS envision an intelligent personal assistant in medical and wellness domain. In this regard, we originate our proposed technology from the assets of dialogue systems and clinical decision support system to develop a dialogue-based Intelligent Medical Platform (IMP), which overcomes the limitations of the existing CDSS and dialogue systems. The proposed innovative incremental learning methodology is capable of adapting internal knowledge structures with user interaction. The knowledge is acquired from diverse sources of knowledge such as structured data (EMR/EHR), unstructured data (text and images), and multimodal sensors. The acquired knowledge is finally verify and validate by the domain experts. The proposed system is equipped with Intelligent Knowledge Engineering Toolkit to acquire knowledge from diverse sources as well as the domain experts' heuristics, experiences, and practices. The proposed knowledge extraction, creation, validation, and its representation methodologies overcome the barriers of knowledge modeling, elicitation, and reasoning.

## II. RELATED WORKS

According to the convergence of medical decision and dialogue system, we focused on both type of literature. Healthcare decision making systems are intended to support physicians, patients and other medical professionals to deal with diagnosis, treatment, and patient in healthcare services. IBM Watson is a popular system to facilitate healthcare professionals, leaders, advocates, influencers, and users through support to achieve remarkable outcomes, fast-track discovery, make essential connections and gain confidence for solving the biggest healthcare challenges. Physicians can provide precision medicine to cancer patients using Genomics [8]. Medexter healthcare designs and developed clinical decision support to provide high-quality software solutions for healthcare domain. The provided systems are essential for the growing density of huge amount of healthcare data and process [9]. Similarly, a healthcare stakeholder, named AllScript [10], delivers different type of services to the patients, physicians, and hospital as consultancy, education, medical related hardware in healthcare domain. The healthcare organization McKesson [11] helps healthcare professionals constantly in applying evidence-based clinical decision support. An intelligent clinical decision support system is designed and developed by a healthcare stakeholder, named ReedGroup [12], to provide healthcare solutions to different medical professionals. Oracle Healthcare Precision Medicine (OHPM) [13] is a web based application designed to endorse healthcare by considering genomic (precision medicine) based testing, personalized efficient decision making and appropriate report generation.

In the current era of technology, personal assistants are growing and become popular to provide recommendations in easy communicational way of natural language dialoguing. Cloud-based speech recognition systems improves web surfing, transportation, health care [14]. The Apple Siri [15] facilitates the users to talk with system using voice communication. Siri talks very faster, easier, and do the things for users quickly. Alexa is Amazon's cloud-based voice service to build natural voice experience for the customers to more intuitive way to communicate with technological systems. It is available on tens of millions of devices from Amazon and third-party device manufacturers [16]. Google Now is the more aspiring developments of Google's search software [17], and it is an intelligent personal assistant to answer questions in the natural language.

## III. METHODS AND MATERIALS

Our proposed intelligent medical platform (IMP) is one of medical platforms which integrates diverse state of the art technologies such as multimodal sensors, adaptive user interaction, and evolutionary medical knowledge generation in order to provide comprehensive medical services. IMP resulted in different type of tools to deal with different services such as *Knowledge Engineering Tool*, *Analytics Tool*, *Evidence Support Tools*, and *UI/UX Authoring Tool* for physicians, patients, and experts of user experience as shown in Figure 1. The IMP platform deals with diverse type of data input resources such as blood pressure devices, smart watch, sleep monitoring devices, glucometer, unstructured text articles, clinical notes, medical pacs, EMR/EHR data, patient health log data. The proposed system extracts knowledge from diverse sources and verifies the knowledge from physicians using *Knowledge Engineering Tool* (KET). The recommendations and knowledge generation needs strong evidences from authentic resources to enhance the trust and satisfaction level of the users on the knowledge, and this responsibility performs by *Evidence Supporter*. In order to monitor the patients' regular activities, behavior, life style, and health condition, the *Analytics Tool* performs very well to give the alerts, reminders, guidelines, and recommendations to the physicians and patients. Therefore, the adaptation of systems' interfaces based on the user experience of system utilization is performed by *UI/UX Authoring Tool*. The foundation of IMP consists of five cores, as depicted in Fig 2. The philosophy of making layers within core is to make it comprehensive and reusable. The responsibilities of each core are very well-defined with proper interface to access the services. The core 1, "*Knowledge Acquisition and Inferencing Layer*" is responsible for knowledge extraction from diverse data sources (i.e. structured, unstructured, and image), and knowledge representation. The core 2, "*Engineering Support Layer*" facilitates the physicians to create, maintain, and validate the interoperable and shareable knowledge using a user-friendly dialogue environment and as an evidence relates the created knowledge with authentic online resources. The core "*Data Acquisition and Persistence Layer*" deals with diverse format of data acquired from multimodal data sources. It is an extended version of our indigenously developed
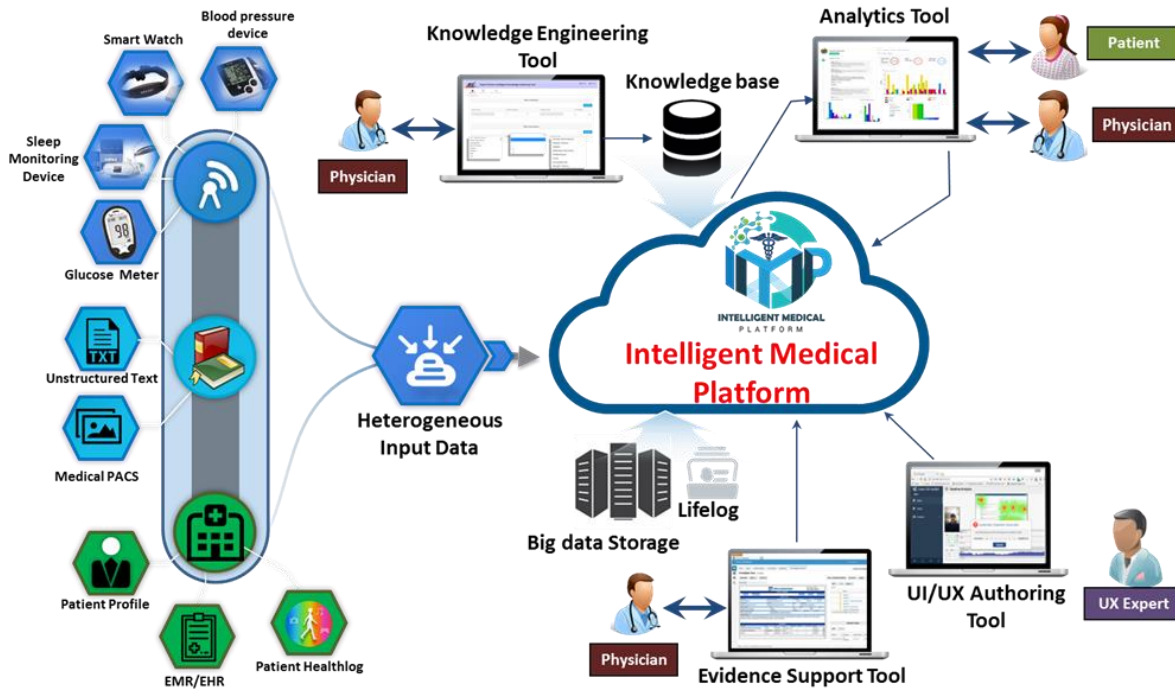
**Figure 1. Abstract idea of Intelligent Medical Platform**

project Mining Minds' Data Curation layer [18]. The realization of usability in terms of user interaction with system and user-friendliness is achieved by "*UI Management Layer*" core. It provides an intelligent way to adjust the user interfaces and dialogue environment based on the collected user experience with the system. The final core, "*Service Integration Layer*" is in-charge of data and knowledge interoperability to integrate the IMP and its knowledge base with existing heterogeneous EMR/EHR systems of multiple hospitals. The details of the each core is described in the following sub sections.

*A. Knowledge Acquisition and Inferencing and Context Recognition Layer*

This core contains two layers; *Context Recognition Layer* and *Knowledge Acquisition and Inferencing Layer*. Following are the brief detail of each layer.

*1) Context Recognition Layer*

This layer contains two components; High Level Context Recognizer and Low Level Context Recognizer. Low Level Context Recognizer is responsible to transform and extract the wide-spectrum of data obtained from the user interaction with diverse sensors to identify different type of activities such as physical activities, users' emotions, locations and behavior patterns [18]. The output of Low Level Context is intelligently combined to identify the High Level Context of the user by High Level Context Recognizer. It identifies more meaningful and semantically rich context of the users.

*2) A. Knowledge Acquisition and Inferencing Layer*

This layer performs its task with help of five basic components: *Actionable Knowledge Evolution and Inferencing*, *Structured Knowledge Acquisition*, *Descriptive Knowledge Acquisition*, *Image-based Knowledge Acquisition* and *Dialogue-based Knowledge Acquisition*. The

The *Actionable Knowledge Evolution and Inferencing* is responsible to handle structured data with the help of *Structured Knowledge Acquisition*. It extracts hidden knowledge from EMR/HER systems or some other hospital management and information systems (HMIS) data. The component has used model to represent the knowledge in a very sophisticated methodology of Ripple Down Rules (RDR). RDR is a systematic representation to acquire and evolve knowledge without depending on knowledge engineers. The extraction of knowledge from textual unstructured data is a challenging task. The component *Descriptive Knowledge Acquisition* is designed to extract knowledge from textual medical resources. The component perform the knowledge extraction process through four major steps which includes unstructured data preprocessing, information extraction, semantic analysis and ontology management.

The *Image-based Knowledge Acquisition* component is provided to classify the image. It consists of four major features including category classification, segmentation, local feature extraction and model collation. Deep Convolutional Neural Network (Deep CNN) model is used for automatic category classification to recognize image and organ types. After classification, segmentation process partitions the image
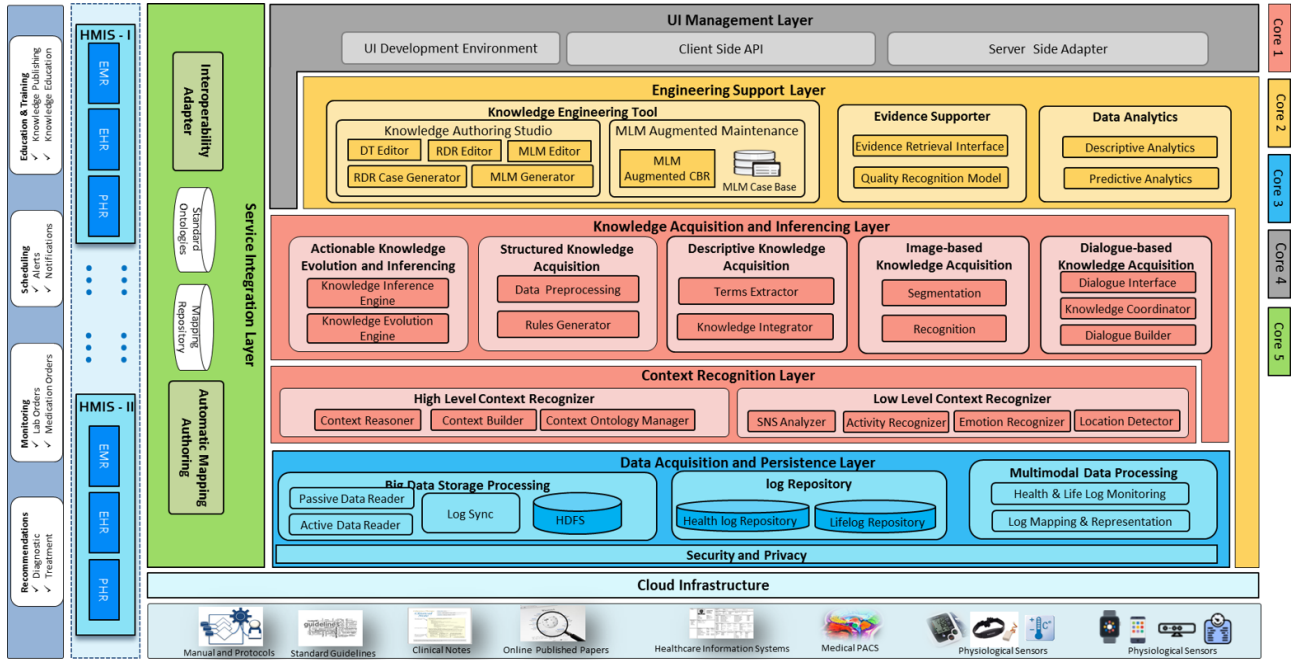
**Figure 2: Architecture of Intelligent Medical Platform**

into meaningful independent region, called Region of Interest (ROI) for processing. Local feature extraction supports to identify the margins of the ROI by extracting features such as points, edges and corners in each segment.

*B. Engineering Support Layer*

In healthcare systems, the experts' knowledge and experience play a vital role in the success of technology to provide right solution for the health issues. Technologically integrated platform can be comprehended when physicians are induced to create and disseminate their knowledge to community using CDSS knowledge bases. Therefore, IMP is provided specially with an *Engineering Support Layer*. The core consists of five main components: *Knowledge Authoring Studio*, *MLM Augmented Maintenance*, *Executable Environment*, *Knowledge Button* and *Data Analytics*. These sub components facilitate the physicians to transform their understanding and experience by creating and validating shareable and interoperable knowledge. Similar to other domain, medical domain has its own vocabulary with terminologies, data models, and knowledge representations. These knowledge representations are in standard format up to very high extent as compared to other domains.

Knowledge authenticity is an essential requirement of medical healthcare domain. The *Evidence Supporter* module provides the knowledge authenticity using high quality of online evidences [19]. It has an ability to relate the most appropriate and relevant online evidences to the knowledge rules and MLMs during knowledge creation and execution time to enhance the trust level of experts as well as other

stakeholders. IMP facilitates the stakeholders (patients and physicians) to communicate with system using multiple channels like text, voice, and image by a dynamic multimodal dialogue environment. Context-aware conversational intelligence module of Dialogue Manager enhances the user-friendliness, user interaction, and user accessibility to healthcare systems.

*C. Data Acquisition and Persistence Layer*

This core consists of three main components: *Multimodal Data Processing*, *Big data Storage Processing*, and *Security & Privacy*. These components induced the ability to gets the multimodal data from multiple sources in structured, unstructured (text, image, and voice) format and persist into non-volatile storage. It acquires heterogeneous data from different hospitals, patient profile, personal interest, and sensory data to store into Health log repository and Hadoop Distribute File System (HDFS) for interminable storage.

Real-time data acquisition from multimodal data sources is a responsibility of *Multimodal Data Processing* module. It acquire real-time data of users' health data from multimodal data sources and map to health-log ontology instances. It handles two kinds of the data; a) Observatory data, which is semantically enriched and stored into health-log repository using its flexible representation and mapping, b) interventional data, which is unstructured and consist of the different biological and physiological sensory data are stored in the big data storage. The sub component of *Big Data Storage and Processing* are working collaboratively. It handles the online and offline request and response of data based on the

utilization of data. All the runtime recommendation requests, responses and dialogues are handle as online by Active Data Reader. In contrast, the Passive Data Reader deals with offline requests of data for visualization, predictive analysis and knowledge extraction. Considering the sensitivity and associated concerns of the collected personalized information, the Security Manager module assure and exhibit adequate privacy and security, not only at the storage level, but also during processing and delivery of services. It employs state of the art existing cryptographic primitives along with indigenous protocols to exhibit more control over possible states of data. For secure storage, AES standard is particularly considered.

### D. UI Management Layer

User acceptance and adoption are critical to having a successful integration of system in health domain with diverse type of stakeholders. An excellent user experience means the system is easy and intuitive. The "*UI Management Layer*" core handles the user interaction with the system in a user-friendly way. It deals with user experience (UX) evaluation during the utilization of Knowledge Engineering Tool interfaces and adapts the user interface (UI) based on the evaluated user experience. The core consists of four main components: Adaptation Engine, Data Collection, Hologram Manager, and UX Measurement. The UX is assessed by measuring and learning from usage behaviors and emotional responses with both implicit and explicit ways by incorporating the human behavior research. "*Data Collection*" module collects the user data through different methods and sensors such as audio, video, biometric & neuromeric, user interaction data, and surveys as self-reported data to reveal the user thoughts, feelings, behavior, and perceptions towards the proposed IMP.

The "*UX Measurement*" is an inferencing and modeling component for UX evaluation. It deals with interaction metrics, emotion and stress metrics, and self-reported metrics. User interaction metrics collects the user interaction and calculating the performance of the system. The different emotional measurements such as audio, video, physiological eye tracking are fused to acquire the complete picture of user emotion-al experience by using the mixed method approach for stress and emotion measurement. The benefit of using multimodal data from different devices (neuromeric and biometric) allow to gain deeper insights into human emotional and motivational reactions, such as fear, happiness, sadness, surprise, anger, disgust, neutrality, engagement, distraction, workload, frustration, and excitement.

### E. Service Integration Layer

In healthcare, interoperability is the ability of different information technology systems and software applications to communicate, exchange data, and use the information that has been exchanged. Data exchange schema and standards should permit data to be shared across clinician, lab, hospital, pharmacy, and patient regardless of the application or application vendor. It has two main components: Automatic Mapping Authoring, and Interoperability Adapter.

Automatic Mapping Authoring component represents the offline phase and performs the authoring and evolution tasks. In authoring, the alignments between the legacy systems model and IMP model is generated. IMP considered FHIR standard as the data exchange and processing format due to its easily adaption advantages. For generalized mappings Sphere [20] matching systems is used for finding the alignments between the models and storing it in the repository in the form of EMR-FHIR mappings. Devices-FHIR mappings are the compatibility of medical devices and sensors with FHIR standard which is necessary for the alignment of devices with FHIR standard. Customization and validation of mappings are performed by the help of human intervention. Evolutions in the mappings are managed with the passage of time as models evolve with the time.

Interoperability Adapter component represents the online phase and uses the existing mappings for conversion among legacy and IMP compatible formats. The interfaces are provided through which IMP services can be accessed. Initially, queries are generated in input format to retrieve mappings from the repository. The retrieved mappings are converted to the final output. The mappings retrieved are managed for the transformation to FHIR format for communication. The converted FHIR message is shared with respective core, where it is utilized for recommendation generation services.

### IV. CONCLUSION AND FUTURE WORK

Intelligent Medical Platform (IMP) exploits novel technologies to support users with eminence of medical services. The platform practices data and knowledge acquisition approaches to evolve the knowledge base. It extracts the knowledge from diverse structured and unstructured data sources. It amalgamates the medical standards for interoperability of knowledge and data to share knowledge among diverse medical institutions.

In future, we will design and develop a holographic environment for easy interaction of users with the system.

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