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Development Of an Integrated Medical Intelligence System Using Ontology and Virtual Data Integration Technique

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Abstract
The aim of this paper is to develop a system that provides for data analytic, data visualization, monitoring and reporting functionalities for clinical decision support using ontologies and data integration technique. This paper presents a medical intelligence system that involves the design and integration of healthcare information recording platform using PHP-MySQL and Java. The system developed provides for medical record storage in a decentralized database, patient's diagnosis record, and database record sharing with other healthcare centers. The system supports clinical decisions by having an ontologies and virtual data integration in order to enhance medical intelligence process. The key concept of the developed medical intelligence system using ontology-based and virtual data integration techniques was to ensure abstraction of data that comes from multiple sources in varying schemas and to have a seamless transition from data into information, then into action. The result showed 96.7% in accuracy.

Keywords: *Hospitals, Data Visualization, Confusion matrix, database*

1. Introduction

Medical intelligence is the ability to detect and cure an ailment on time with minimal effort. It requires vast knowledge on disease symptoms, cure, and this can only be achieved by having a data warehouse build from the knowledge of medical experts. To apply medical intelligence effectively, the healthcare condition of the patients must be ascertained. The health-care condition of a patient is defined as all the past and current medical and social information about the patient that may affect the professional immediate and short-term management of that patient (Chih-Lin, 2019). In this paper, this information corresponds to all the diseases, syndromes and social issues that are diagnosed for the patient, the signs and symptoms (including family medical history), the problem assessments performed (i.e., medical, social, cognitive, and mobility tests), and the current interventions, either pharmacological, rehabilitative, nurse care, social care, counseling, and special medical services. In order to describe patient conditions, several national and international encoding systems have been proposed for diseases and procedures (Shortliffe, 2015). Also, the ability to describe patient's condition on time will result in a speedy healthcare delivery system. This requires techniques for data integration, warehousing and representing knowledge in biomedicine. At some time, health records of the patients and detail of the doctors are stored in different hospitals or stored in different location of the database, it is difficult to collect these records (Boyi, 2019). For that, ontology can be constructed to resolve these problems and to make correct decision at emergency period. Ontologies are one of the most successful ways of representing actionable knowledge in biomedicine (Rosse, 2019). Two of the reasons for this success are their ability to capture biomedical knowledge in a formal but simple, powerful and incremental manner, and their easy application in the reasoning processes performed by medical decision support systems (Ouwens, 2015).In health care, the most common, complex and resource-consuming clinical cases to deal with correspond to chronically ill patients, who are a kind of patients that deserve long term and simultaneous assistance provided by several sorts of professionals, as for example family doctors, specialists, nurses, or social workers. In order to deal with this highly variable kind of patients, one need mechanisms to personalize the knowledge describing both the condition of these patients (each individual patient is a potential different case with specific diseases, syndromes, social needs, signs and symptoms), and the intervention plan for these patients (the actions to be followed for different patients are eventually very varied). But we also need mechanisms to assess whether the decisions and recommendations on these patients are correct or not in part because the possibilities of over- and under-treat these kinds of patients can be very high. Also, integration becomes a crucial challenge as heterogeneous data is generated by various healthcare systems. This has to do with how to integrate various types of data including patient demographics and environmental data, clinical monitoring systems, pathology and radiology imaging data, textual data from clinical reports etc. Bianchi et al. (2019) describe the integration of clinical, environmental and genetic data and point out with examples how ontologies are used to normalize data from various disparate systems. This paper examines how to utilize modern technologies available and design a system that assists health workers in decision making. The system will allow for easy and fast reach to information. One of the core objectives is to support physicians, nursing, laboratory, and radiology staffs in various hospitals to exchange data and information electronically. This is due to importance of time that helps decision makers implement necessary and most appropriate procedure for patient, especially if provided by internet. In the health sector, patient's data are scattered in different hospitals and resides in different database. Collecting or integrating these data together is a big challenge for clinicians, health service managers, and researchers who routinely obtain and process data from an array of sources. Also, the representation of the data gathered is of concern as wrong representation of data can mislead the clinicians. In the existing medical record system, there exist some challenges which includes., lacks of analytic, data visualization, monitoring and reporting functionalities for clinical decision support, lack of data integration across various hospitals. The aim of this paper is to develop a system that provides for data analytic, data visualization, monitoring and reporting functionalities for clinical decision support using ontologies and data integration technique.

2. Review of Related Works

Table 1: Summary of Related Works

Author	**Techniques**	**Work done**	**Limitations**
Binggui, *et. al* (2022)	natural language processing (NLP)	They were able to show the strength and possibility of NLP for delivering smart healthcare	Lacks understanding various human languages
Awais (2019)	machine learning	Development of Machine Learning (ML) toolset for clinical decision support	Requires improvement in user authentication and security of data
Marut, 2016	Ontology-based	and clinical reminder system that link clinical guideline knowledge with patient registries	The paper didn't integrate electronic health record (EHR) standards
Madhura, 2020	open data integration platform	facilitates centralization of data assets	Lacks analytics, data visualization, monitoring and reporting functionalities for clinical decision support
Alexander (2017)	machine learning	Combined NLP features from free-text physician notes with structured data to train a supervised classifier to predict CRT outcomes	Was not able to predict CRT outcome with both high precision and high recall
Chih-Lin, 2019	machine learning	facilitating personal health care, reducing costs of health care, and improving outcomes	The work was carried out using a single hospital and may not represent the actual facts when you broaden the scope.
Sozan, 2019	Adaptative Neuro-Fuzzy System (ANFIS)	The obtained simulation results demonstrate the efficiency of using ANFIS model in the identification of heart attacks	The intelligent system was limited to heart attacks only
Serdar, 2018	Survey	A major finding of the survey is that although significant advances have been made in introducing AI technology in critical care, successful examples of fielded systems are still few and far between	Theoretical review. No practical implementation
Vishesh, 2017	cloud computing	Addressed the challenge of sharing medical data	Didn't incorporate medical intelligence

Dipti, 2019	Expert System	help a great deal in identifying those diseases and describing methods of treatment to be carried	Lacks data integration
Soltan, 2017	Expert System	Able to give appropriate diagnosis and treatment for two heart diseases namely; angina pectoris and infarction	Is limited to two heart diseases
Ighoyota, 2017	Fuzzy	The analysis clearly shows the effectiveness and accuracy in the system performance through false result elimination	Lacks data integration
Alexander, 2020	Multi Agent Enhanced Business Intelligence	Results indicate that the pMAEBI managed stores performed better (in terms of profit) than the comparison stores	Narrowed to product pricing
David, 2020	ontology-based personalization	Helps health-care professionals to detect anomalous circumstances such as wrong diagnoses, missing information, unobserved related diseases, or preventive actions	Needs specialized knowledge to operate
Agustina, 2018	Framework for Comparison	This survey describes seven systems and three proposals for ontology-based data integration.	It is a survey
Bostjan, 2018	ontology based	bridges the gap between ontology-based integration and service-oriented architecture by enabling dynamic and transparent integration of information which is provided by services	The problem of splitting the query into static and dynamic query was not addressed fully.
Ali et al., 2018	Virtual Data Integration	They developed a Virtual – Data Integration Framework (V-DIF) that meets most of the users' expectations	concentrate mainly on data integration process and avoid or ignore the other two processes (inconsistency detection and resolution)
Ali, 2018	Mapping Approach	Provides a linkage between the fundamental components required to provide accurate and unambiguous answers to the users' queries from the integration system	Cannot use the sources of the data to resolve the duplicate through source preferences.

Vinoth, 2019	Ontology based	By using Internet of Things will help us to cure the patient in a short period of time	The paper didn't integrate electronic health record (EHR) standards
Taqdir, 2017	Intelligent-Knowledge Authoring Tool(I-KAT)	Developed technologically integrated healthcare system	Increased complexity
Richter and Weber 2016	case based reasoning	Medical dataset	Existence of many problems without solutions
Jagannathan, 2019	KNN	The performance of CBR applications was enhanced	The missing data values of some attributes have been handled while others are not treated
Asma, 2018	Decision tree	Prediction of presence and absence of diabetes	It is a review of techniques and no model was developed
Kapil, 2017	Support Vector Machine (SVM) and Artificial Neural Network (ANN)	Diagnosis heart disease	The accuracy is low when compared to another research
Nassim, 2018	Fuzzy logic	Modeled clinical practice guidelines	Is not a dynamic system
Kamal (2021)	NLP/Deep Learning	data like laboratory reports, diagnosis reports, medical images, demographic information about the patient, clinical notes was computerized	Low accuracy in predictions

3. Methodology and Analysis of the System

Object-oriented analysis and design methodology (OOADM) was adopted in this thesis, and it is a set of standards for system analysis and application design. It uses a formal methodical approach to the analysis and design of information system. Object-Oriented Analysis and Design Methodology (OOADM) elaborates the analysis models to produce implementation specifications. The OOADM approach is motivated by the kind of system we desire to develop. We desire to build a usable and evolvable application. The very nature of the proposed system, in which navigation is combined with the inherent difficulties of dealing with multimedia data, needs an OOADM approach. The interface of Web apps is more complex than in traditional software systems, navigation and functionality should be seamlessly integrated and the navigational structure should be decoupled from the domain model of the app, therefore OOADM was chosen for its functionalities, in that it allows object-oriented abstractions for analysis and design of information-intensive web applications. Besides the modeling abstractions, it also provides a methodology which guides a developer through different activities in the web application development.

3.1 Method of Data Collection

Data were gathered as fellow:
Review: document about patient's medical record was reviewed for the purpose of updating knowledge. This is very essential as it involves direction and result achievement.
Observation: health infrastructures were observed, strategic locations of network that can enhance electronic services were also observed.
Interview: health stakeholders were interviewed to gather information on how to serve them better in public health care.

3.2. OOADM Methods Used
Activity Diagram
Class Diagram

Activity Diagram

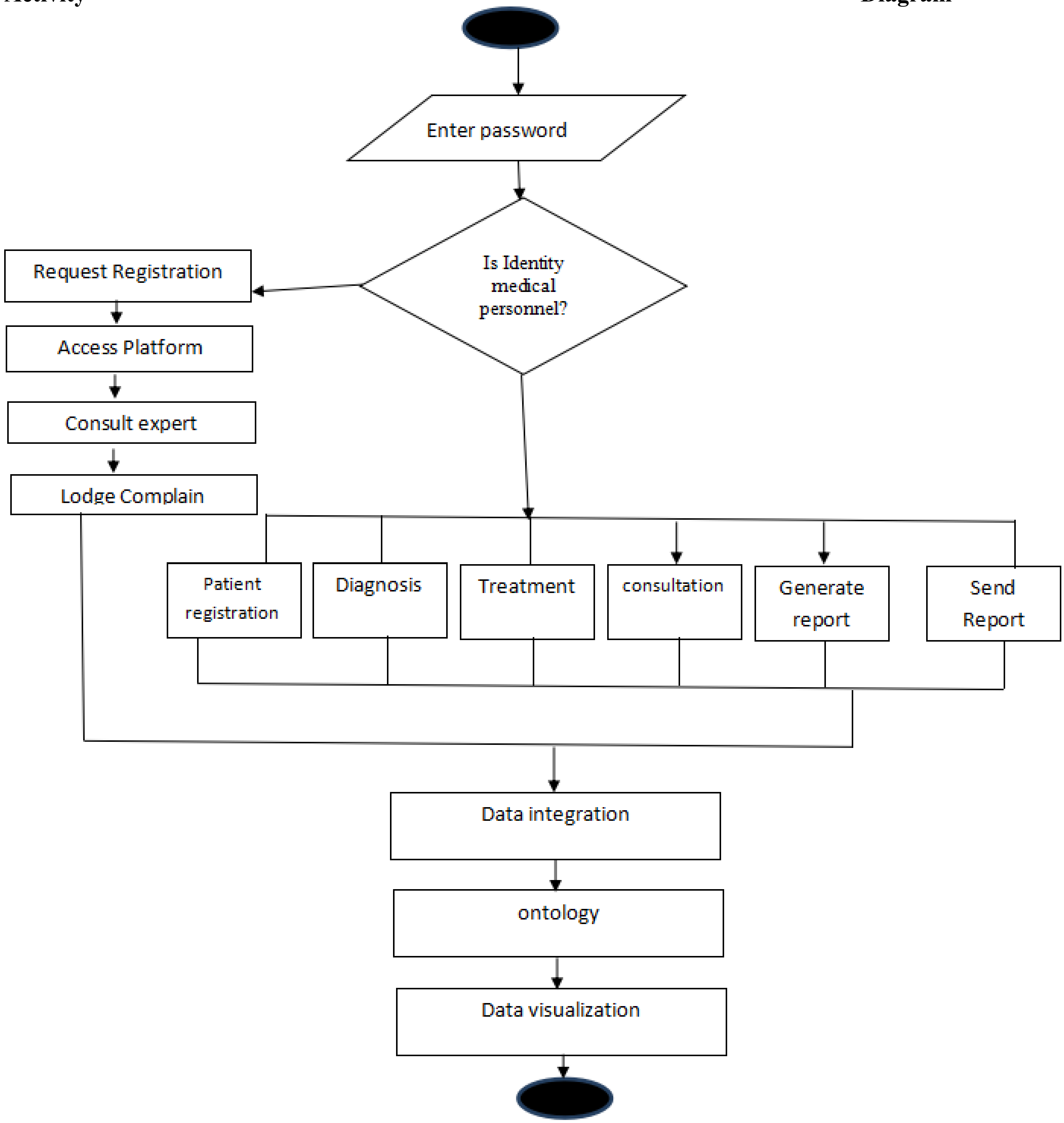

Figure 1: Activity Diagram

The activity diagram as shown in figure 1 entails the ontology-based and virtual data integration process. The process flow of the system would be boosted with the software agents as indicated in the data integration layer of the system design. The data integration layer is where the ontology-based and virtual data integration process takes place and it is the aspect of the medical intelligence process that the research is enhancing.

Class Diagram

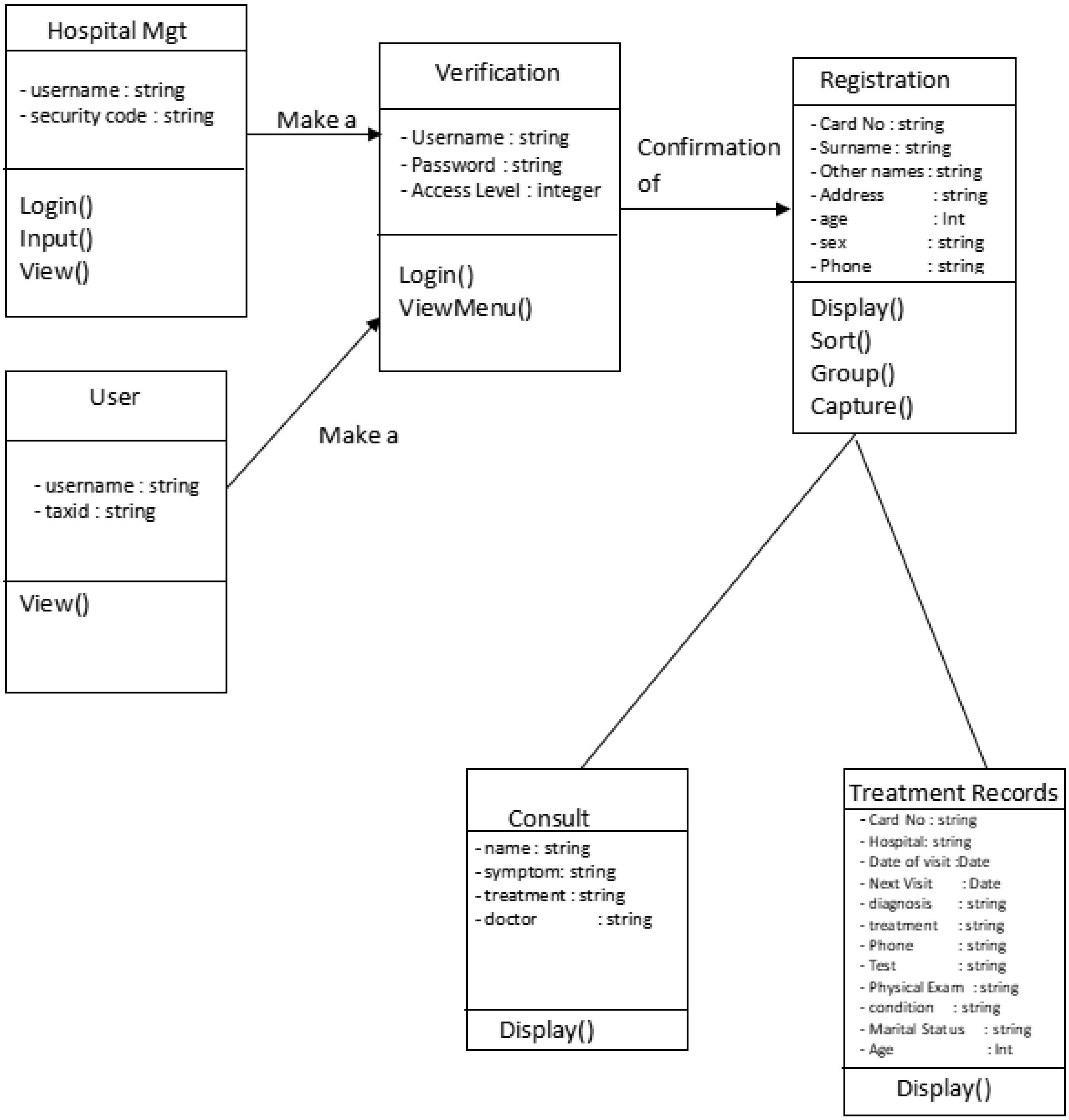

Figure 2: Class Diagram of the System

Class diagrams are one of the most useful types of diagrams in UML as they clearly map out the structure of a particular system by modeling its classes, attributes, operations, and relationships between objects. Figure 2 shows various information sources that is needed at various stages of the data integration processes. The standard class diagram is composed of three sections:

Upper section: Contains the name of the class. This section is always required, whether you are talking about the classifier or an object.

Middle section: Contains the attributes of the class. Use this section to describe the qualities of the class. This is only required when describing a specific instance of a class.

Bottom section: Includes class operations (methods). Displayed in list format, each operation takes up its own line. The operations describe how a class interacts with data.

4. Performance Evaluation and Discussion

A performance metrics can be derived from the confusion matrix as show in table 2 and equation, which show the accuracy (AC) of the hybrid model for enhanced business intelligence process.

Table 2: Confusion Matrix

Observed

		True	**False**
	True	TP	FP
Predicted	**False**	FN	TN

$$AC = \frac{a+d}{a+b+c+d}$$

a = True Positive
b = False Positive
c = False Negative
d = True Negative

During the testing, 30 tests were carried out to see how it can accurately identify and classify the patient diseases based on the knowledge acquired from the dataset using medical intelligence. Table 3 shows the performance grading of the medical intelligence.

Table 3: **Confusion matrix applied to test dataset**

Observed

		True	**False**
	True	12	1
Predicted	**False**	0	17

Table 2 shows that out of 30 tests conducted using medical intelligence, 12 are True Positive and were predicted correctly. 17 were detected to be True Negative and were predicted correctly. 1 was False Negative (shows the wrong classification) while it is not. Finally, a model of performance metrics can be derived from the confusion matrix as show in equation, which shows the accuracy of the system.

Substituting the values we have
AC = (12+17) / (12+17+0+1)
AC = 0.967 i.e. 96.7% accuracy in predicting the outcome of the diagnosis (see table 4).

Table 4: **Performance Results Obtained**

Technique Applied	**Accuracy in classifying the symptoms**
Medical Intelligence	96.7%

5. Conclusion

The software developed provides for medical data analytics, data visualization, monitoring and reporting functionalities for clinical decision support using ontologies and data integration technique. The system also presents an improved medical intelligence process system that can provide medical intelligence to physician in more than one area of disease. More also it made possible to electronically schedule next visit date and patients' treatment and level of responds to treatment. The software performance was tested using a dataset of patient's record. The test result shows 96.7% accuracy in predicting the outcome of the diagnosis.

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