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AN IN-DEPTH EXPLORATION AND ANALYSIS OF THE ADVANCED INFORMATION TECHNOLOGIES AND SOFTWARE MODULES DESIGNED TO MAP UNDER NORMAL AND PATHOLOGICAL CONDITIONS ACCURATELY

Chandan Bansal

Shivaji College, University of Delhi, New Delhi, India

ABSTRACT

Intelligent information technology tools, leveraging artificial intelligence, are increasingly recognized as crucial infrastructure and strategic assets within e-healthcare. These technologies, built upon classification models utilizing data mining methods, facilitate the assessment and prediction of human health states, enabling diverse tasks such as enhancing monitoring effectiveness, improving student functional states during learning, and forecasting patient condition severity throughout treatment.

INTRODUCTION

In the pursuit of digital transformation, the establishment of patient-centric digital healthcare ecosystems, driven by information technology (IT), telemedicine, and mobile medicine, emerges as a pivotal objective within the Global Strategy of Digital Healthcare spanning 2020-2025 [1]. Digital transformation encompasses "a process aimed at enhancing an entity by inducing significant changes to its attributes through a blend of information, computing, communication, and connectivity technologies" [2, p. 118].

The realm of research and development in digital medicine technologies is burgeoning with novel pursuits related to the management and dissemination of medical data, their subsequent analysis for addressing individual and population health concerns, as well as the realms of treatment, rehabilitation, and prevention of public health ailments [3]. Researchers assert that digital technologies play a pivotal role in empowering patients to access quality healthcare irrespective of geographical constraints, enabling them and their families to readily acquire health information and treatment alternatives, and facilitating access to healthcare facilities tailored to their needs [4]. Telemedicine tools, IT-enabled analysis and prognostication of patient conditions using artificial intelligence, alongside blockchain technologies, the Internet of Things, and robotic services, deployed and employed across diverse healthcare entities, are now regarded not merely as infrastructure but as strategic assets [5].

Presently, numerous medical research endeavors harness artificial intelligence methodologies, notably machine learning, to construct classification and regression models for evaluating and prognosticating patient conditions across a spectrum of diseases: from diagnostics and therapeutics for urolithiasis [6] to diagnostic imaging in orthopedics [7], modeling and forecasting blood glucose dynamics [8], cardiovascular risk prediction [9 – 11], and scrutinizing the pros and cons of integrating artificial intelligence into primary healthcare systems.

Intelligent information systems, designed for comprehensive analysis, detection, and prediction of disease progression, necessitate reliable and ample personal health data. The integration framework for the exchange of digital medical data among diverse stakeholders involved in healthcare provisioning amalgamates several core functional components: formalized business processes delineating information flows and participant attributes (actors) within the researched process, a subsystem for digital medical data storage, and functions (algorithms) for accumulating and subsequently exchanging digital medical data.

Efficient delivery of medical services hinges on ensuring prompt and accurate diagnosis of an individual's health status, coupled with the forecasting and monitoring of changes throughout treatment. Leveraging information technologies and AI-based systems for medical data analysis forms the cornerstone of this endeavor. Leveraging existing mechanisms for interaction among various healthcare participants—ranging from healthcare institutions at various tiers to medical professionals and patients—is pivotal in fostering population engagement in decisions (Social participation) impacting their health.

INTELLIGENT INFORMATION TECHNOLOGIES FOR ASSESSING HUMAN HEALTH STATES IN NORMAL AND PATHOLOGICAL CONDITIONS

The widespread integration of information support in safeguarding and enhancing human health necessitates the advancement of novel approaches to creating information methodologies for obtaining real-time data and intelligent techniques for evaluating changes in human health states across a broad spectrum of tasks. These tasks span from enhancing control effectiveness and enhancing an individual's functional state in work environments to facilitating medical and diagnostic procedures. Our developed comprehensive IT framework comprises three primary stages: data acquisition and initial processing, state analysis utilizing Data Mining methods, and offering forecasts of state changes or recommendations for enhancement.

Our proposed intelligent information technology for assessing human health states has been applied to various domains, including studying operator activity reliability under information load conditions [12], evaluating outcomes of surgical interventions such as conduit implantation in children with severe heart defects, and analyzing treatment results for patients with cardiac and diabetic conditions. This paper presents outcomes from addressing specific tasks using our developed IT, adapted to support monitoring students' functional states (normal) and assessing patients' condition severity (pathology). For each specific IT, a corresponding information model of the investigated patient's condition is formed at the initial stage.

Intelligent information technology for monitoring and correcting students' psych-functional states aims to provide personalized psychological support within the educational setting. Educational initiatives focus on nurturing professional development while preserving students' well-being. Numerous studies indicate a decline in students' health and associated challenges in their social adaptation.

The student's functional state encompasses physical and mental facets, reflecting changes during the learning process. Leveraging new information technologies enables comprehensive assessment, monitoring, and timely correction of students' functional states. A key objective of he developed IT is identifying individual variations in students' psycho-functional states, pertaining to components like intellectual, emotional, and personal-motivational aspects. Consequently, the IT is geared towards monitoring these components and the overall state of each student, providing tailored psychological support based on monitoring results.

The information technology for monitoring and correcting students' functional states encompasses three primary stages: determination of functional state characteristics, analysis and evaluation of the student's functional state using comprehensive indicators derived from Data Mining methods, and implementation of individualized psychological support programs (Fig. 1). The initial stage involves determining component functions, including intellectual (perception, attention, memory, and thinking), emotional (impression and expression of experiences), and personal-motivational functions (interpersonal relations: conformity and non-conformity according to T. Leary's concept).

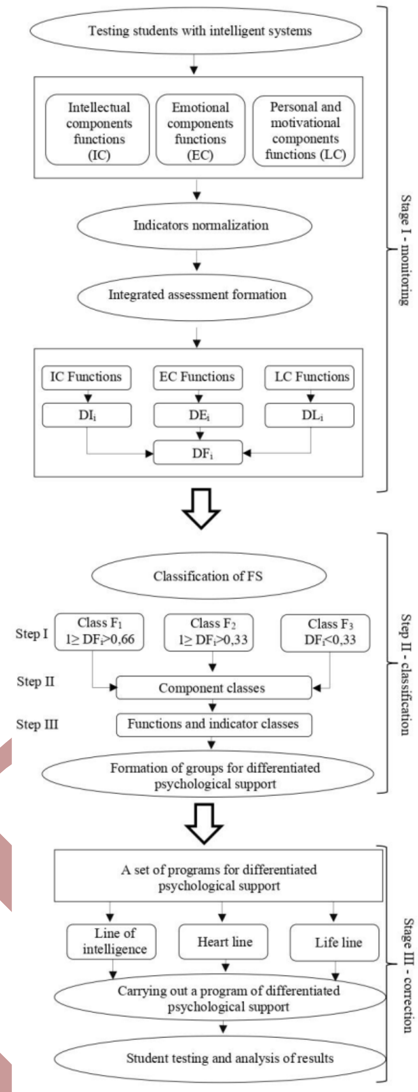

Figure 1: Intelligent Information Technology for Monitoring and Adjusting Students' Psych-Functional State.

The functions' characteristics are determined using established psycho diagnostic tests, and the resulting scores are normalized for calculating the integral psychophysiological state index.

Analysis of students' psych-functional state characteristics (Stage II) employs a hierarchical model. It begins with the highest level - the integral index - then systematically reveals the state of intellectual, emotional, and personal-motivational components and their functions. Three functional status classes are distinguished based on obtained estimates (DFi):

- Class F1: good functional condition with $1 \geq DFi > 0.66$;

- Class F2: satisfactory functional state with $0.66 \geq DFi > 0.33$;

- Class F3: unsatisfactory functional state with $DFi \leq 0.33$.

At this stage, differentiation is determined for each student based on functions whose status is deemed unsatisfactory or satisfactory.

In Stage III, a program of personalized mental support is developed, considering changes in the intellectual, emotional, and personal-motivational components' states. These programs, constructed akin to a constructor, comprise training sessions targeting relevant aspects of mental activity. Leveraging information technology enables adjustment and sustained maintenance of students' functional states at a high level, thereby enhancing the effectiveness of the learning process.

Intelligent information technology for assessing patient severity during treatment has also been developed. Multiple studies classify the severity of conditions such as connective tissue dysplasia in children based on various initial indicators. Utilizing decision tree methods, an optimal classification tree of disease activity levels was derived. This allowed for the identification of necessary cardiovascular markers: integrated STT form indicator (Ind STT), T-wave amplitude (Amp T(II)), alpha angle (Angl QRS), and T-wave symmetry factor (Sim T(I)).

Decisive classification rules are established based on decision tree splits:

- High disease activity (D=3): if (Ind STT) ≤ 49.5 then D=3;

- Moderate activity (D=2): if (Ind STT) > 49.5 and (Amp T(II)) > -160 then D=2;

- Initial activity (D=1): if (Angl QRS ≤ 75.5 and (Sim T(I)) ≤ 0.57 then D=0),

where D represents disease severity, Ind STT is the integrated STT form indicator (lead II), Amp T(II) is T-wave amplitude (lead II), Angl QRS is the alpha angle, and Sim T(I) is the T-wave symmetry ratio.

These decision rules form the foundation of the severity assessment algorithm (Fig. 2).

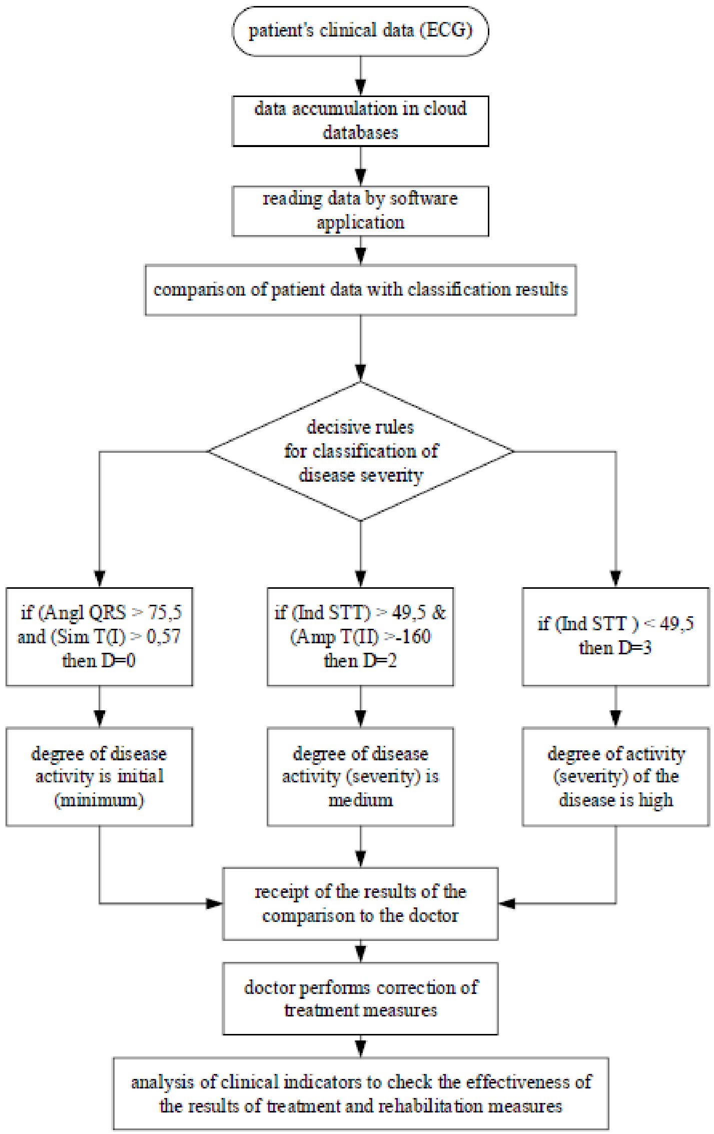

Fig. 2 Classification algorithm.

Therefore, to aid in treatment strategy selection, the clinical data of an individual patient are juxtaposed with class prediction outcomes, enabling the determination of disease severity. Subsequently, based on this comparison, the physician delineates treatment strategies, thereby adjusting the local protocol to some extent.

INFORMATION SPACE IN THE DIGITAL HEALTH ECOSYSTEM

The proposed technologies serve as the foundation for developed software modules tasked with acquiring, analyzing, storing, and exchanging medical information. One such module, ExchangeDMD (ExchangeDMD-1), and the specialized "ClinAss" module utilize client-server architecture. Server-side specifications include Apache 2.4.23 or Nginx 1.5.13 software, MySQL 8.0.17 for database management, and PHP 8.0 as the main programming language. The client-side utilizes HTML 5 as the primary markup language, CSS 3 or CSS 4 for styling, along with additional libraries jQuery 3.3.1 and Bootstrap 4.0. Application interfaces employ JavaScript React development technology based on the ECMA 5 standard. For desktop computers, the client part is developed on Windows, IOS, or Unix platforms, while for mobile devices, it is tailored for Android, IOS, or Windows Mobile platforms.

Currently, the development and deployment of software modules for storing and exchanging clinical information are recognized as pertinent by numerous E-Health developers. The functionality of these modules for medical data exchange aims to establish a unified information space within the digital health ecosystem, thereby enhancing the efficiency of utilizing accumulated data in diagnostic and treatment processes.

We conduct an analysis of information flows realized during interactions among key participants in medical care provision: patient-doctor, patient-healthcare facility, doctor-doctor, etc. Several groups of information flows are delineated (see Fig. 3).

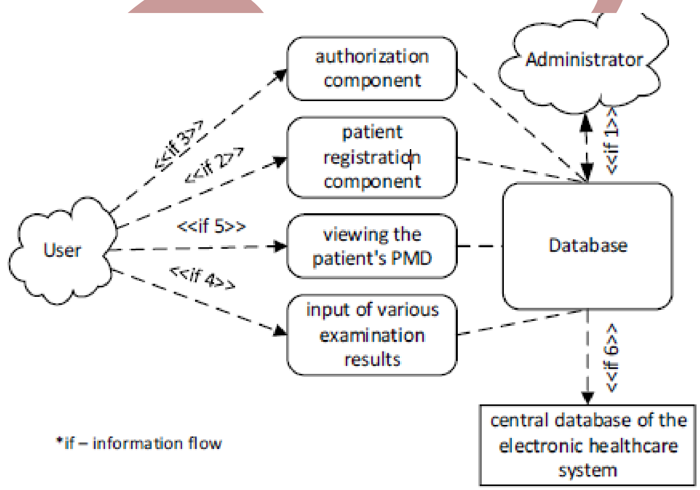

Fig. 3 Information flow diagram.

- IF 1: Administration management, hardware resources, and connection interfaces. This initial flow encompasses actions such as managing system administrators' lists, database management, configuring virtual machines, backup control, integrity checks for the database, monitoring OS version, log file checks, user creation/editing/deletion, access rights management, and connecting additional modules.

- IF 2: This flow ensures that examination results entered by the patient, with mandatory preregistration and authorization, are securely saved.

- IF 3: Utilized by physicians to access necessary patient information and preserve their conclusions derived from data analysis. This flow encompasses processes like authorization, inputting physician notes, recording treatment and services provided, and generating various documents (referrals, certificates, etc.) [11].

IF 4 is designated for gathering and storing results from various instrumental examination systems, clinical laboratory tests, and similar diagnostics. PI 5 pertains to patient data provided by consulting professionals involved as needed. Upon receiving a suitable referral, the specialist consultant reviews the patient's data and offers advisory opinions, treatment recommendations, medication prescriptions, and so forth.

IF 5 relates to patient information obtained from engaged specialist consultants, if necessary. A specialist consultant assesses the patient and provides advisory opinions, treatment recommendations, medication prescriptions, and the like.

Thus, integrating software modules and systems for evaluating individuals' functional states, diagnosing specific pathologies, and facilitating the efficient exchange of medical information should prioritize enhancing the effectiveness of E-Health information flows.

CONCLUSION

The developed information technologies rely on classification models utilizing Data Mining techniques to evaluate human health states and forecast changes. This enables diverse tasks, including enhancing control effectiveness, improving student functional states during learning, and predicting patients' condition severity during treatment.

The establishment and integration of software modules for storing and exchanging clinical information ensure the operation of a comprehensive information space within the digital healthcare ecosystem. This space is dedicated to effectively utilizing accumulated data in diagnostic and treatment procedures.

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