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INTELLIGENT DECISION-SUPPORT SYSTEM IN RHINOLOGY

Annotation. *This paper presents the new intelligent decision-support system for rhinology domain. Model of system was developed and complex of mathematical models for improving of decision-making process was proposed. Using of computational intelligence methods for significant feature extraction will provide more high accuracy of decision-making process in rhinology. It has been demonstrated that implementation of CFD-simulation for surgery planning will allow ENT specialists to avoid of unnecessary interventions.*

Keywords: *Decision-support, Feature extraction, Computational intelligence, Classification, CFD-simulation.*

Introduction

Medical diagnosis in “Ear Nose Throat” (ENT) domain includes a variety of objective and subjective methods for evaluation of patient’s status. Among them are Acoustic Rhinometry, Rhinomanometry, Peak Nasal Flow, Nasal Spirometry, different questionnaires like Visual Analogue Scale (VAS) [1, 2] and other. Most of rhinological diagnoses are based on derivation of diagnostic parameters from rhinomanometric measurements, ENT-experts knowledge, Computer tomografy (CT) results and clinical data. During last ten years the fluid dynamic simulation approach for modelling of motion of airflow in nasal cavity has become widespread. Now there is a gradual integration of the CFD-technology into clinical practice.

While the technical level of diagnostic for cardiovascular, pulmonary, even ear diseases are quite high, functional diagnostic in rhinology is still much less advanced.

Such systems in ENT domain have to provide two basic processes: decision-making for treatment/surgery and planning of surgery. The main goal of the decision-support system is to deliver additional and reliable information to the ENT specialist. It will allow to increase precision of diagnostic accuracy, an effectiveness of surgery as well as to reduce a health-care costs and treatment duration.

To deliver an integrated solution, on the one side, we should take into account that data derived from variety of external sources will comprise different types of variables: numerical, linguistic etc., on the other side it is ongoing developments in several apparently unrelated fields (e.g. the mathematics of the Navier – Stokes equations describing the motion of fluids, CFD modelling, computational intelligence methods). It requires applying the complex of mathematial models.

The important requirement for such system is also to realize the patient-specific approach of treatment. It means the decision-support system (DSS) should analyze each case and recommend the most appropriate treatment/operation considering heterogeneity and incompleteness of initial data. System should also perform a set of decision-support tasks for providing to assisting of ENT-specialist:

– decision-making for diagnostic purposes, including surgical intervention;

– planning of surgical intervention process;

– assessment of surgery's results.

These tasks include the data input, storage and analysis procedures as well as training of system, generation and validation of ruls for decision-making process.

The principles of system's functioning should provide:

– an interaction between the core of the system and micro services;

– suitable tools of representing and processing of ENT-domain knowledge;

– possibility of replenishment of the knowledge database and training of system;

– versatility of the system within the diagnostic process in ENT subject domain.

The main task of current paper is to develop an intelligent decision support system that includes the complex of technologies for heterogeneous data processing and provides the information required to support the medical decision in ENT domain.

Design of intelligent decision-support system

The decision-making task in medicine is a set of methods that includes objective and subjective evaluation techniques. Considering a variety of ENT domain data sources, like CT-services, Rhinomanometers, HD-videoendoscopy, patient's questionnaires, CFD results, medical expert conclusions, these sources produce a lot of heterogeneous data. So, the core of system consists of the platform which may interact with external services. It is Service-oriented architecture that based on the request/reply design paradigm for synchronous and asynchronous applications. System may be integrated into hospital environments or can work as a local station.

Intelligent decision-support system should comprise three main components: intelligent interface (II), knowledge data base (KB) and decision-making block (DM) to support doctor in his professional activity. Intelligent interface consists of data input, output, preprocessing and data interpretation blocks. It is based on Web services gateway which provide an access to the knowledge base. Inference mechanisms and computational intelligence processes will interact with the knowledge base using standard protocols and data exchange conventions [3].

All generated data will be stored in a knowledge base, where machine learning (ML) algorithms will operate to extract new hidden features of patient's data to support doctors' decisions. The KB will consist of knowledge of ENT domain including information from business rules, guidelines, expert knowledge, CFD simulation outputs, 4PR measurement results etc.

Decision-making block is based on complex of mathematical methods which includes both classic theory of decision-making [4] methods and methods of computational intelligence. Implementation of computational intelligence methods allow us to extract meaningful features of initial dataset and apply the classification, clasterization, dimensionality reducing procedures etc. The structure diagram of intelligent decision support system is shown in Fig.1.

In the Fig. 1 we can see blocks of MS – microservices (CT, RM, CFD), DI – data input, DP – data preprocessing, S&A – statistics and aggregation, KB – Knowledge database, DB – database, SSP – subsystem of surgical planning, ES – ENT specialist, DO – data output, KI – knowledge interpretation, DM – decision-making block, DMM – decision-making methods, DA – data analysis (DA - data intelligent analysis, SA –spectral analysis, CTP – CT postprocessing).

Advantage of proposed system is applying a complex of mathematical models that allow analyzing the process of nasal breathing using different approach: hydromechanics, processing of time series with chaotic properties, machine learning algorithms for extracting relevant information about the patient's conditions. The required technologies will be integrated into an environment where ENT specialis will interact with the system via a web interface, providing the information required to support the medical decision.

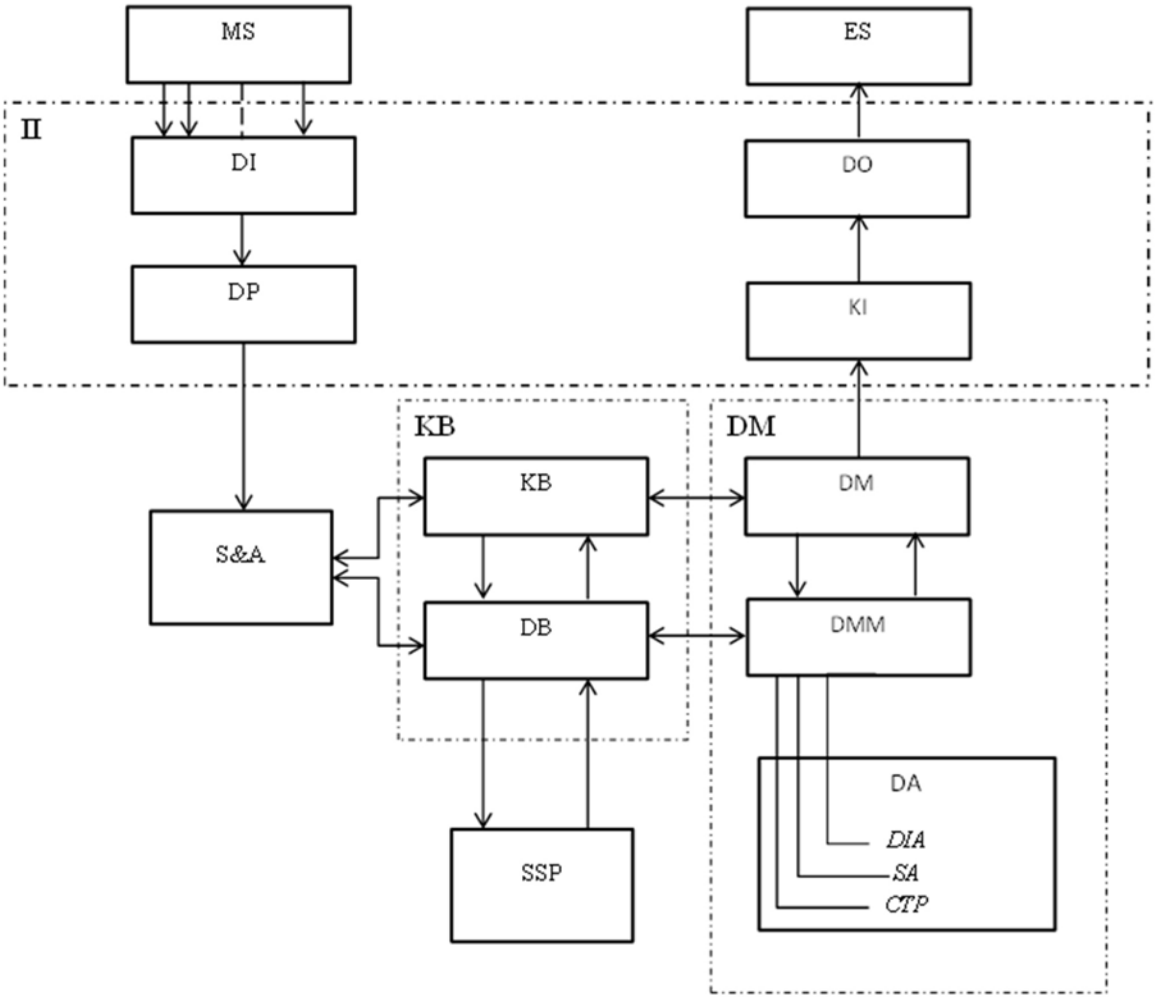

Fig.1 – The intelligent decision support system in rhinology

The initial data transferred from microservices can hold noises and missing values. Therefore, the preprocessing stage is required. Data preprocessing stage includes several techniques like data cleaning, data reduction, data transformation, which are described in detail in [5, 6]. The particularities of time series processing approach was described in [7]. Analysis of nasal breathing characteristics using hydrodynamics was presented in [8]. Particularities of computational intelligence methods implementation were described in [9].

We can formalize the model of intelligent DSS using (1):

$$IDS =< II, DM, KB, DB, MB, AB, SSP >, \qquad (1)$$

where II − intelligent interface for interaction with MS and ES, DM - decision-making model, KB - knowledge database, DB - data base, MB - base of models, AB - base of algorithms, SSP - subsystem of surgical planning.

Decision-making model (DM) analyzes the task using description model of problem and chooses an appropriative model for decision-making. Description model of problem is described as a set of features which include a symptoms, diseases, additional diagnostic data and relations between them. So, we can formulate the decision-making model according to (2):

$$DM =< DSM, KB, DB, MB, AB, DR >, \qquad (2)$$

where DSM - description model of problem, DR - decision rules for choosing of decision-making method.

Model of knowledge base may be presented as a structure:

$$KB =< DSM, DT, DMN >, \qquad (3)$$

where DSM - description model of problem, DT - decision trees model for obtaining of diagnosis, DMN - meta-model for decision modeling. Description model is represented as ontological model and uses semantic relations between objects of diagnostic process. DMN is standard which provides a powerful meta-model, notation and semantics for decision modeling of business processes. Decision Tables modelled according to the DMN [3] recommendation can include parameters essentials for CFD-simulations. Cases describe real cases or experiments (scenarios elaborated and presented by a story telling engine) and are modelled using Case Management Model and Notation (CMMN).

Base of models consists of set of mathematical models for intelligent analysis, analysis of biomedical signals, CT postprocessing, models of hydromechanics, decision-making models in stochastic uncertainty conditions. These models process data for decision-making purposes.

The data base comprises expert descriptions, obfuscated CT-images, an annotated reconstructions, that will be represented in Standard Tessellation Language (STL) and will be extracted directly from CT data, topologies, documentation of real cases, results of CFD simulation, data from questionnaires, Rhinomanometry measurement results, hydrodynamic coefficients and characteristics of nasal cavity.

We can write the base of algorithms using (4):

$$AB =< ATSP, AC, AHRC, ACTP, AGVC >, \quad (4)$$

where $ATSP$ - algorithms of time-series processing, AC - classification algorithms, $AHRC$ - algorithms of hydrodynamic coefficients and characteristics calculation, $ACTP$ - algorithms of CT-scans post-processing, $AGVC$ - algorithms of conclusions generation and verification.

Model of subsystem for surgical planning (SSP) may be written as follow structure:

$$SSP =< KB, DB, MB^*, AB^*, EPB >, \quad (5)$$

where KB - knowledge database, DB - data base, MB^* - base of models for CFD simulation and 3D model creation, AB^* - base of algorithms for CFD simulation including algorithms of numerical simulations and 3D model creation, EPB - base of methods for evaluation and prognosis of surgery outcome.

Structure of information technologies

Description of diagnostic process in ENT was performed in [10]. The main stages of information technology of nasal breathing function diagnosis is shown in Fig. 2

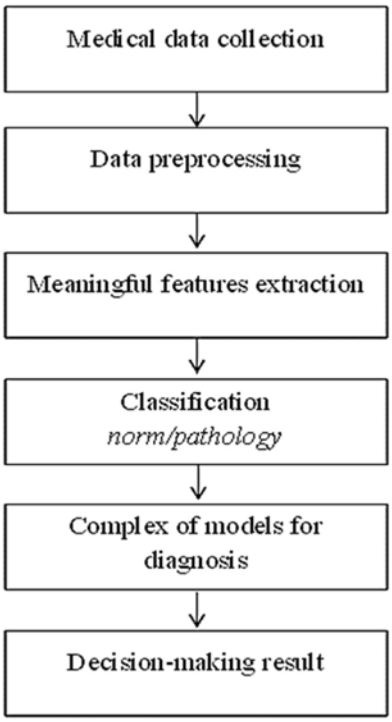

Fig.2 – The main stages of information technology for diagnosis

Process of surgery planning is realized in subsystem of surgical planning (*SSP*). This should be formalized as a separate information technology. The respiratory system is a vital system which mainly tubular in nature and powered by the lung. Any kind of obstruction of this transport system will result in a variety of diseases than can have a profound effect on wellness and quality of life. Structural damages of nasal cavity can be treated by variety of surgical procedures. Many of these procedures are performed daily on thousands of patients and have led to an inpressive empirical knowledge database. Some of these procedures have statistically significant failure rates, indicating a need to study in depth the fluid dynamics before and after intervention. So, it would be highly desirable to predict the outcome of an intervention before surgery, particulary for complex cases where a detailed empirical database is lacking. The basic stages of information technology for surgery planning are presented in Fig. 3.

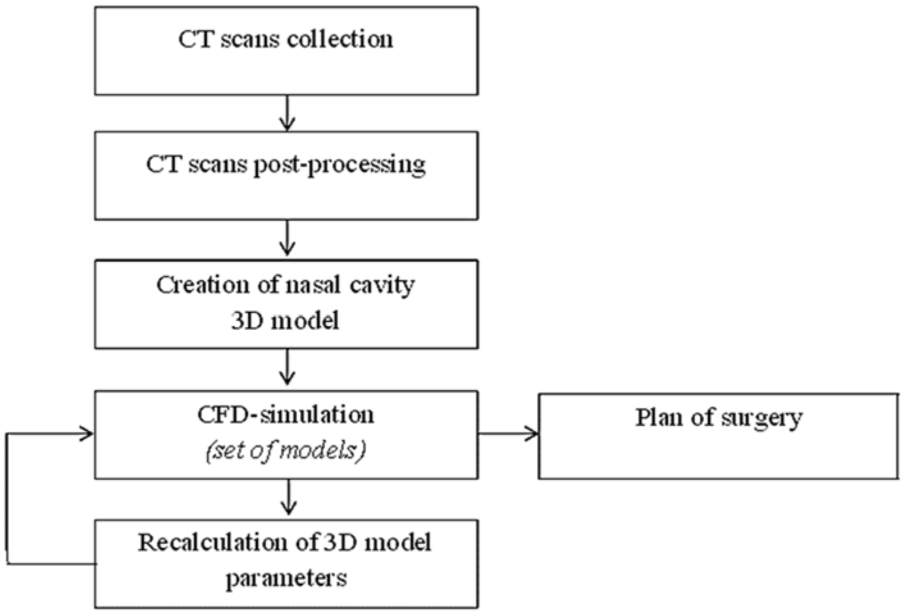

Fig.3 – The main stages of information technology for planning of surgery

The basic steps of surgery planning process based on CFD simulation are the following: pre-processing of CT scans; creation of 3D model; grid generation; boundary and initial conditions definition; choice of fluid-structure solver; data visualization and interpretation.

Conclusions

The intelligent decision-support system for rhinology domain was developed. Such system will bring into the toolbox of the ENT specialist a modern computer-based tools and techniques including CFD simulations, computational intelligence and time series processing approach – capable to improve the nasal and paranasal pathologie diagnosis and to plan surgeries in an effective way. System is based on intelligent interface, knowledge data base and decision-making block to support ENT specialist in his professional activity. Complex of mathematical models for decision-making process takes into account the heterogeneity of initial data. The paper demonstrates a potential of using the computational intelligent methods for meaningful features retrieval of medical data in ENT domain as well. The main stages of information technologies for diagnosis and surgery planning were proposed. CFD-based information technology will allow doctors to avoid an unnecessary surgical interventions and develop plan of operation in short time period.

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