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Telemedicine DSS-AI Multi Level Platform for Monoclonal Gammopathy Assistance

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***Abstract*—The proposed work describes preliminary results of a research project based on the realization of a Decision Support System -DSS- platform embedding medical and artificial intelligence -AI- algorithms. Specifically the telemedicine platform is suitable for the optimization of assistance processes of patients affected by Monoclonal Gammopaty. The results are related to the whole design of the platform implementing a DSS based on a multi-level decision making process. Starting from the main architecture specifications, is formulated a flowchart based on different alerting levels of patient risk including artificial intelligence -AI- decision supporting facilities. Finally, the perspectives of the performed research are discussed.**

***Keywords*—Telemedicine, Digital Assistance, Decision Support System, Artificial Intelligence, Monoclonal Gammopathy.**

I. Introduction

The telemedicine is an important research topic suitable for homecare assistance and dehospitalization processes [1], where the point of care -POC- technology allows to support the diagnosis thus facilitating the patient status monitoring. In this direction the platforms based on artificial intelligence -AI- [2]-[4] behave as decision support systems -DSSs-, providing patient health status predictions. The health prediction can be estimated by means of artificial neural network -ANN- or Long Short-Term Memory -LSTM- algorithms [2]-[4] or other self-learning algorithms. A good approach to improve telemedicine platform is to combine medical algorithms with AI ones. Concerning medical algorithms, important research advances have been performed in myeloma studies [5]-[7]. The goal of the proposed work is precisely the matching between AI algorithms and medical ones to support decision making process before the Multiple Myeloma diagnosis and during the evolution analysis of the Monoclonal Gammopathy. The proposed different medical analysis steps allow to formulate a multi-level DSS tool enabling an automated alerting system supporting decisions or assistance actions. In the proposed paper we will discuss preliminary results of a multi-level DSS platform enabling decision making processes for patients potentially affected by Monoclonal Gammopathy. The discussion is mainly focused on the design of the frontend/backend design and of the innovative DSS algorithm. Finally, the perspectives of the performed research are discussed.

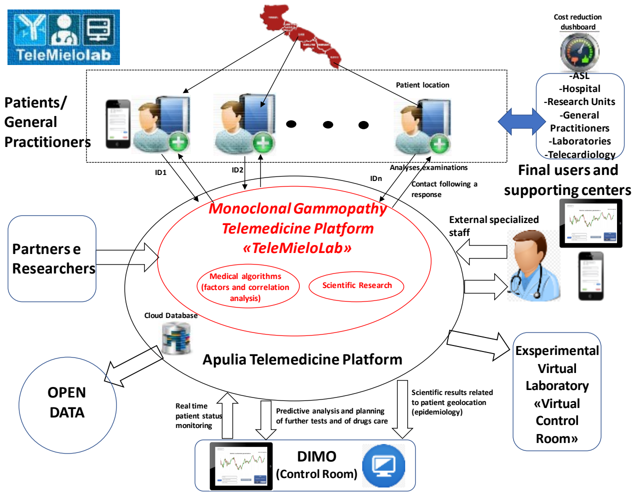

Fig. 1. "TeleMieloLab" platform architecture.

II. Project Architecture and Main Specifications

In this section is provided the full framework of the telemedicine system by describing the project architecture of Fig. 1, and the specifications of the whole platform embedding the DSS algorithm. Successively is described the frontend/backend system design and DSS data input.

A. TeleMieloLab platform and project framework/specifications

The object of the main research project is the creation of the "TeleMieloLab" telemedicine platform, supporting assistance activities of Azienda Sanitaria Locale -ASL-, laboratory analyses, general practitioners, specialized doctors and hospital facilities, focusing the application on patients suffering from Multiple Myeloma. The main goal is to facilitate the hospital work by allowing the patient data travel thus optimizing patient visits and the human resource management inside the clinic. Each patient will be identified by an identification number (ID) tracing all the performed analyses and diagnoses. Through this platform and by means

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of a "Virtual Control Room", are monitored in real time the patients improving an intelligent pre-screening. This evaluation is supported by the application of AI algorithms to identify possible correlations between the factors considered predominant of the Monoclonal Gammopathy. The AI algorithms potentially predict degenerative phenomena by processing historical patient data and other factors influencing the pathology (endogenous and exogenous), by providing a complete overview of the patient screening. Following the first screening, it will be assessed if the patient will have to undergo further tests by optimizing the personalized medication administration. The patient data processing by the DSS will allow the formulation of a therapeutic stratification. This study will be useful to find possible correlations and criticisms for the health risks of patients affected by Monoclonal Gammopaty. Using the prototype platform, the general practitioner will be contacted by message or by e-mail from the control room if threshold values are exceeded establishing an already advanced pathology, or if there is a reformulation of the pharmacological treatment. The platform will allow also the teleconsultation between other external specialized staff thus optimizing data analysis and diagnosis. The patients will be in continuous contact with medical personnel by means of a chat/chatbot/message system. The virtual laboratory also includes an OpenData database of scientific/statistical results, and other information useful for patients and the scientific community. By selecting different laboratories having an "active" participation in the "TeleMieloLab" virtual laboratory, will be optimized the whole regional telemedicine system.

B. Backend and Frontend Design and parametr storage

The backend design of "TeleMieloLab" is shown by the flowchart of Fig. 2, indicating the actor rules and the related specified functions such as:

- -the laboratory will register new patient and will add/read exams;
- -the patient will read his exams or his physiological parameters by adding new measurements;
- -the general practitioner will read the history of each patient by adding new data;
- -the specialized staff (control room and external specialized staff) will read all patient data, will include new analyses, and will process the DSS outputs in order to optimize and to align the therapeutic pattern.

The frontend design is illustrated by the mockups of Fig. 3 reporting the main application functions provided by the following fields: patient ID, different exams parameters, electrophoresis, other information, symptoms, adverse drug reactions, message, chatbot, chat, historical data visualization, patient status prediction, cardiological images, AI image processing, data updating. The preliminary experimental dataset layout about parameters includes: Haemoblobin (Hb), Monoclonal Component (MC), Creatinine (crea), Calcium (Ca++), Immunoglobin G (IgG), Immunoglobin A (IgA), Immunoglobin M (IgM), Free Light Chains (K/L), Beta2 Microglobulin (Beta2), Proteinuria.

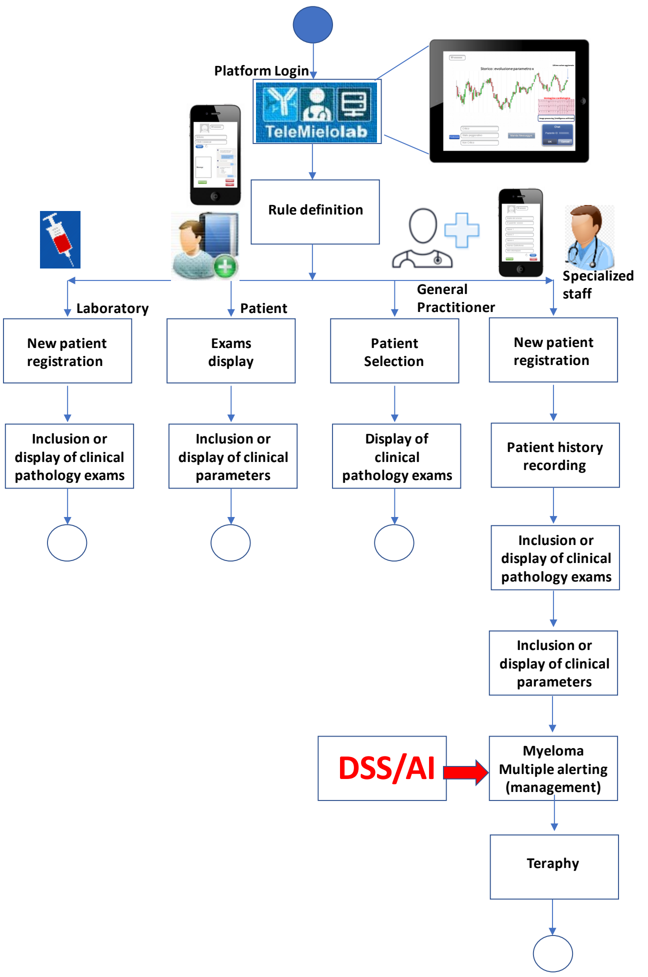

Fig. 2. Backend design of the platform.

Fig. 3. Frontend design of the mobile apps: (a) general practitioner mobile app; (b) patient mobile app; (c) specialized staff mobile app.

III. DSS Multi-level Algorithm

Focusing the attention on the DSS/AI engine indicated in Fig. 2, has been structured the DSS multi-level flowchart of Fig. 4 based on the formulation of three following analysis levels. The DSS level 1 (zoomed in Fig. 5) combines the MC and the proteinuria results with predicted ones generating a first Monoclonal Gammoathy alerting message (alert 1). The DSS level 2 (zoomed in Fig. 6 and in Fig. 7, Fig. 8, Fig. 9, Fig. 10, Fig. 11, and Fig. 12 in each sub-workflow) compares other parameters such as HB, Ca^{++}, creatinine, IgC, IgA, and IgM with predicted ones by detecting critical conditions (HB under 11 g/dL, Ca^{++} over 10 g/dL, creatinine over 1.5 mg/dL, IgG over 3.5 g/dL, IgA over 2 g/dL, IgM over 1 g/dL). The alert condition of DSS level 2 is classified as alert 2 of possible Multiple Myeloma. The DSS level 3 (zoomed in Fig. 13) enables the alert 3 condition of a very probable Multiple Myeloma. This alerting level combines the prediction of all the parameters and other analysis results (i.e., circulating or intracellular microRNA) with Beta 2 and FLC results (critical conditions are for Beta2 over 3mg/L and for FLC under 0.26 or over 1.65). The alerting levels defined by the algorithm are:

-Alert 1: Monoclonal Gammopathy;

-Alert 2: Possible Multiple Myeloma;

-Alert 3: Very probable Multiple Myeloma.

Figure 5 is the zoomed part of the flowchart of Fig. 4 indicating the DSS level 1 structure characterized by MC and proteinuria measurements. Figure 7, Fig. 8, Fig. 9, Fig. 10, Fig. 11 and Fig. 12 represent the zoomed parts (sub-workflows) of the flowchart of Fig. 6 (DSS level 2) indicating HB and Ca^{++}, creatinine, IgG, IgA, and IgM alerting threshold levels, respectively. Figure 13 shows the zoomed DSS level 3 workflow Beta2 and FLC threshold limits and microRNA information supporting DSS in Multiple Myeloma diagnostics.

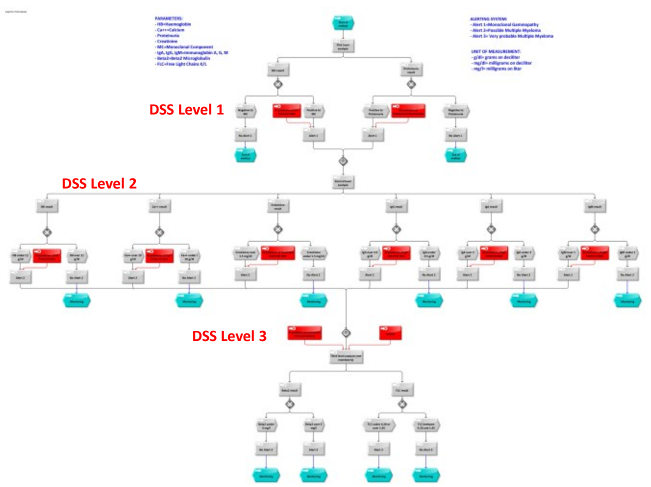

Fig. 4. Multi-level DSS flow chart.

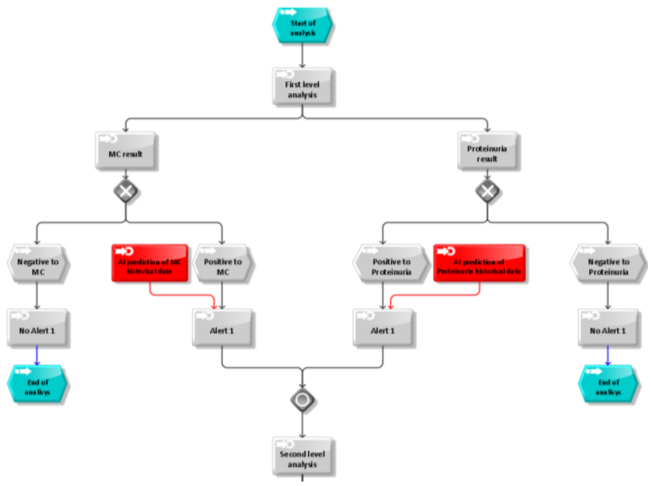

Fig. 5. DSS Level 1.

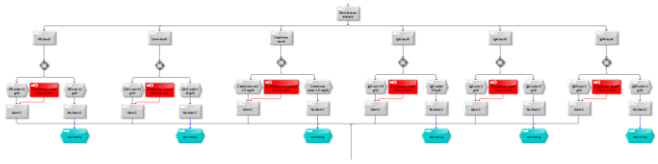

Fig. 6. DSS Level 2 with six sub-workfow.

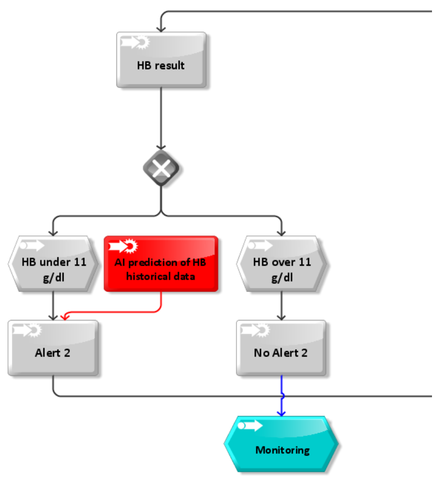

Fig. 7. Sub-workflow 1 of the DSS level 2.

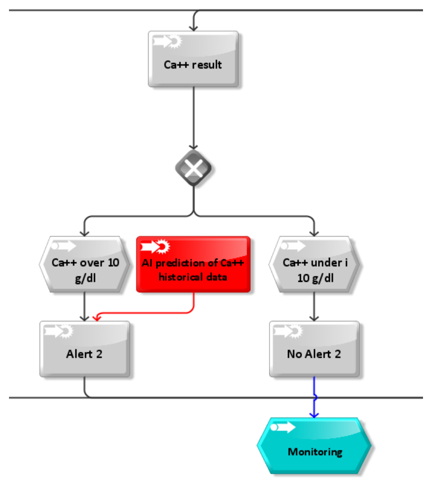

Fig. 8. Sub-workflow 2 of the DSS level 2.

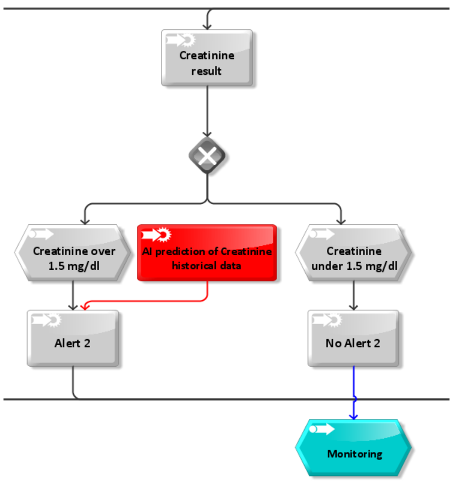

Fig. 9. Sub-workflow 3 of the DSS level 2.

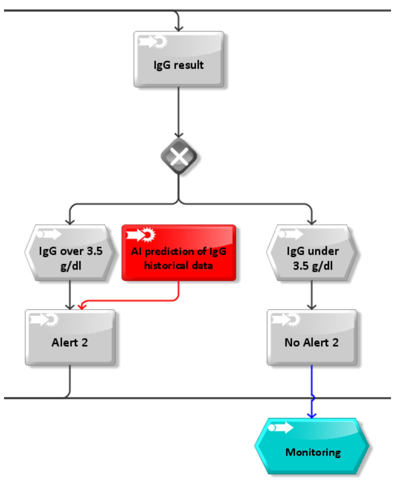

Fig. 10. Sub-workflow 4 of the DSS level 2.

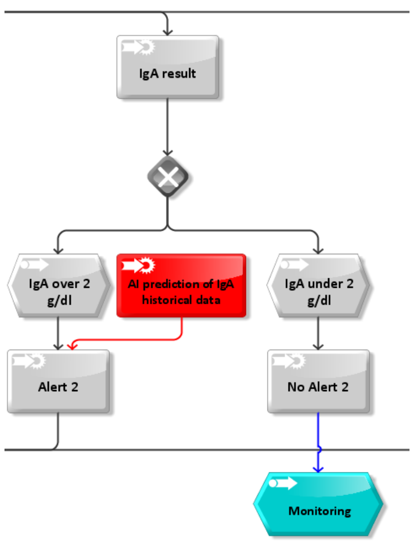

Fig. 11. Sub-workflow 5 of the DSS level 2.

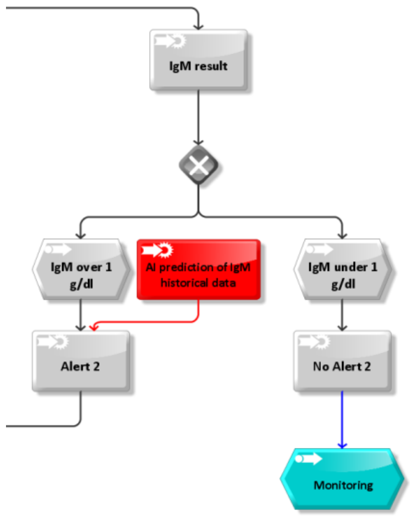

Fig. 12. Sub-workflow 6 of the DSS level 2.

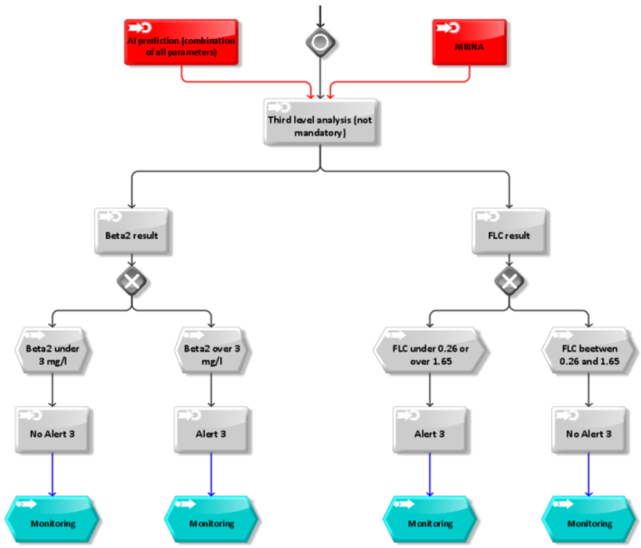

Fig. 13. DSS Level 3.

In Fig. 14 is illustrated a Konstanz Information Miner KNIME workflow implementing multilayer perceptron (MLP) algorithm which is a class of feedforward ANN. This workflow proposes an example of data analysis method able to predict medical conditions. In particular has been applied the DSS level 2 concerning HB prediction for a monitored patient (see Fig. 15 where is checked an alerting condition also for the predicted HB value). Data input used for the DSS calculus have been extracted from a MySQL database and loaded in the local repository by means of an Excel file.

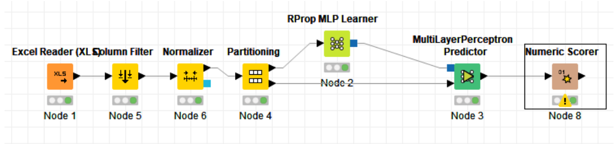

Fig. 14. Multilayer perceptron (MLP) ANN predicting HB: the Rprob MLP learner block is able to learn the model with patient historical data and the Multilayer Perceptron Predictor block predicts the next HB value.

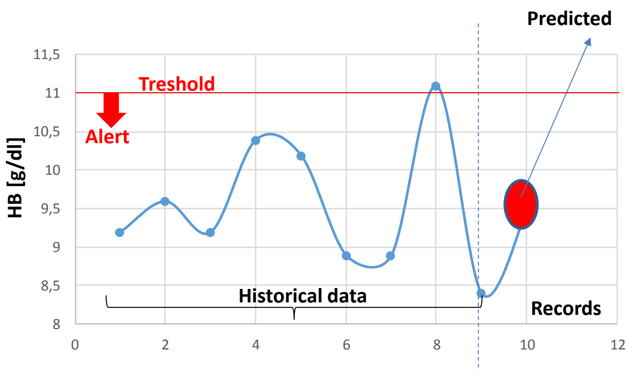

Fig. 15. Historical and predicted measurements of Hb and threshold limit indicated in DSS level 2.

IV. Perspectives And Research Improvements

The basic research will be improved by using blood or bone marrow samples from patients with monoclonal gammapathy symptoms, to assess the value of SNPs (single nucleotide polymorphisms) and microRNA as predictive biomarkers for myeloma evolutionary state (see DSS level of Fig. 3). In particular, intracellular miRNAs will be evaluated using innovative assessment methodologies in order to increase the detection sensitivity. Intracellular miRNAs will be obtained using magnetic polystyrene beads (Dynabeads M-450 Pan B) coated with a monoclonal antibody for the analysis of multiple myeloma through expression levels of CD38 in plasma cells [8]. Intracellular miRNAs samples can be later used for epigenetic expression and characterization studies. Another aspect that will be analyzed during the project development is the integration in the platform of different medical smart sensors able to facilitate the homecare assistance processes. In this direction will be defined measurement and medical protocols according with Internet of Things -IoT- and Health Level Seven (HL7) standards [9],[10]. All the project results will be used to extend the study on epidemiology aspects by using Big Data systems to find possible correlations of Multiple Myeloma with other exogenous variables such as environmental pollution, food, metabolism, etc.

V. Conclusion

The work proposes preliminary results of the "TeleMieloLab" telemedicine project, by discussing the main project specifications, the backend/front design, the DSS flowcharts design and research perspectives. The study is focused on the formulation of the multi-level DSS flowchart embedding medical algorithms and AI ones supporting the data analysis and patient status prediction. The proposed platform is integrable with the actual Apulia Telecardiology platform. Experimental tests on patients are under investigation.

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