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Remote health care monitoring based on swarm intelligence for home care monitoring

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Abstract*—A swarm intelligence-based procedure to detect critical conditions of a patient, affected by a specific disease, at an early stage in absence of clinician, is proposed. The procedure is to be integrated inside a remote health care system for patients at home, where some physiological parameters related to a specific disease are being monitored. A significant variation in the monitored parameters can lead the patient to a critical state, thus the proposed method is aimed at predicting a possible future bad condition of the patient on the basis of past measurements. Moreover, different physiological parameters contribute to diverse degrees in dissimilar diseases; consequently, a swarm intelligence-based method is proposed for optimizing the weight of each parameter for a more accurate diagnosis. The proposed approach has been validated experimentally under the framework of the industrial re- search project Patient Diagnosis and Monitoring at Domicile (PA- DIAMOND: co-funded by EU and the company Filia srl, Caserta, Italy).

1. INTRODUCTION

MEDICAL prognosis is a complicated task based on both scientific knowledge derived from state of the art and medical judgment inferred from clinician experience. In recent years, many home health monitoring systems have been pro- posed. Patients affected by a specific disease are monitored by means of a medical protocol, based on periodical measurements through biomedical transducers of some physiological parameters related to the disease. Among them, one of most promising trends is related to non-invasive monitoring, owing to the intrinsic lack of the physical presence of a caregiver. Typically, the acquired data are sent via Internet to a remote center, where clinicians analyze the data and take decisions. Patient data are sent through e-mail, or images and physiological signals over Internet.

However, the equipment cannot predict imminent health hazard, and sends a red-alert signal only when one or more physiological parameters overcome pre-defined thresholds according to a medical protocol. Conversely, the development of tools with some auto-decision making support, suitable as a preventive device for an early prognosis of problems related to a specific disease, is a fascinating improvement in telemedicine research area.

The most diffused approach is to state the prognostic problem in terms of a meta-heuristic optimized search for the best solution. One of most promising approaches is swarm intelligence. One of the first algorithms for automatic prognosis was presented in based on decision tree classifiers, while, in methods based on classical reasoning structures, such as Bayesian Belief Networks, are found. Moreover, in lasts years, different methods aimed at predicting imminent health hazard of a patient, in a reliable way have been proposed.

However, recent innovations have introduced novel algorithms outperforming the classical methods and are more likely to be accepted in the medical community. In particular, particle swarm optimization (PSO) has gained increasing popularity owing to its ability to solve efficiently and effectively a plethora of problems in science and engineering.

Nevertheless, these prognostics methods exploit mainly empirical knowledge acquired preventively from generic experiments and then used to diagnose the condition of a specific patient under observation. Conversely, a correct prognosis should be guided mainly by the anamnesis, i.e., by the analysis of data collected on the same patient heretofore and by his previous illness. This misconception brings to the limited acceptance of automatic prognostic systems by clinicians, the mainly obstacle to their development and success.

In this paper, a meta-heuristic PSO-based method for in-time automatic prognosis, suitable to be integrated in a remote health monitoring system, is proposed. The method predicts automatically the most plausible future critical condition of a patient, by assessing his current state from home health remote monitoring. Experimental validation results of a case study on chronic obstructive pulmonary disease (COPD) in the framework of the research project Patient Diagnosis and Monitoring at Domicile.

2. BACKGROUND ON PARTICLE SWARM OPTIMIZATION

Swarm intelligence is a modern artificial intelligence discipline concerned with the design of multi-agent systems with main applications in optimization problems and in robotics. The design paradigm for these systems is different fundamentally from more traditional approaches. Instead of a single sophisticated controller governing the global behavior of the system, several simple entities cooperate to exhibit a desired behavior

In PSO, each particle (i.e., a potential solution) “moves” within its search space. As each optimization procedure, a fitness function has to be defined and maximized (or minimized) according to the problem itself.

The velocity of each particle is modified iteratively by its personal best position (i.e., the best position found by the particle so far, with the highest scoring according to the fitness function), and the global best position found by all other particles. As a result, each particle searches around a region, defined by its personal and its neighbor’s best positions. This iterative procedure terminates when a pre-defined condition is achieved.

3. THE PROPOSED METHOD

In the following, (i) the basic ideas, and (ii) the prognostic procedure of the proposed in-time prognosis method are illustrated.

3.1 Basic Ideas

The main aim of the in-time prognosis is to predict a critical condition of a patient, before its actual occurrence. Within a given clinical framework, after the diagnosis, a prognosis is carried out by evaluating the disease, its usual trend, possible future complications, and the patient conditions above all. As praecox the diagnosis, as in time the prognosis will be, and consequently more effective the therapy. In home-care monitoring, the prognosis medical process is carried out experimentally by analyzing suitable past physiological data of the patient under observation, on the basis of clinical experience.

Multiple physiological parameters are involved, thus a specific set of parameters concerning the disease of interest is determined. Correspondingly, a suitable monitoring model is defined. On this basis, a data acquisition system is designed for measuring actual values of the parameters and identifying the model.

The acquisition system is mainly based on several biomedical devices/transducers, aimed at acquiring the physiological quantities of the model. A medical protocol is also defined for a proper monitoring of the patient’s disease. Data are then retrieved periodically in order to accomplish the protocol. Physicians are interested in risk parameters, i.e., if a patient is approaching to either a high, moderate, or low patho-physiological risk state. Then, the risk is represented as a linguistic variable, rather than an ordinary variable, by means of fuzzy logic.

This allows a model, for predicting a low, moderate, or high-risk state of the next reading for a patient, to be built easily. With this aim, triangular and trapezoidal fuzzy operators have been used. Physiological parameters can contribute in diverse degrees for different diseases, thus in the proposed method the criticality is predicted by defining suitable weights for the specific set of parameters of interest. Then, the values of the parameters are upgraded by optimizing these weights.

In this way, the pro- posed in-time prognosis is essentially an optimization problem in continuous domain. Therefore, a meta-heuristic approach is well suited. The PSO represents a good trade-off between complexity and reliability from the point of views of implementation and quality of the found solution, respectively.

3.2 Prognostic Procedure

The algorithm of the proposed prognostic procedure is shown in Fig. 1. In the following, the main steps are detailed.

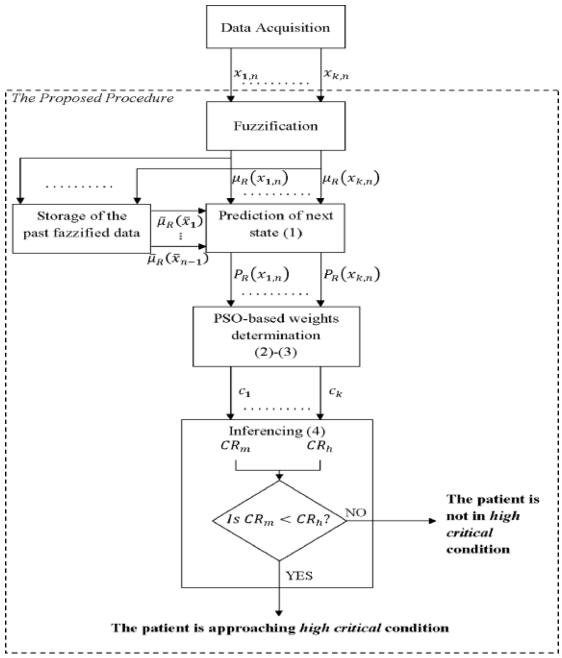
1) Data Acquisition: Depending on the considered pathology, several physiological parameters are involved in the diagnostic process, thus the first step is to define the quantities measured by the medical protocol to be processed for the disease of interest.

2) Fuzzification: The patient's acquired data are fuzzified on the basis of suitable membership functions. Such a preliminary transformation converts the periodic measures into likelihoods that the path physiological parameter of the patient is high, low, or moderate, according to a set of reference values. The Fuzzy sets are implemented according to the limits provided by well-settled medical and clinical criteria.

4) PSO-Based Weights Determination: Each value $P_R(x)$ assessed by means of (1) is weighted in order to compute a number of criticality indexes, providing a sound basis for deciding whether the patient is in critical condition or not. With this aim, a multidimensional continuous function, difficult by its nature, is to be minimized.

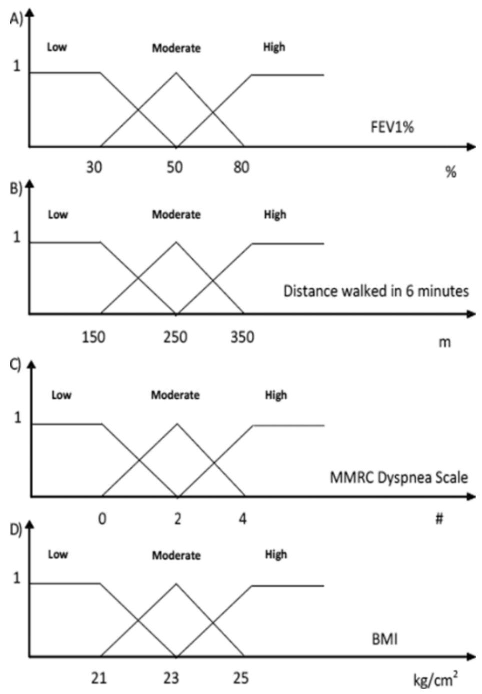
5) Inferencing: Predictive diagnosis implies a crucial decision whether the patient is in critical condition or not. With this aim, specific rules based on the assessed value ofthe probability in (1) are defined according to clinician experience. From a cybernetic point of view, making diagnosis can be though as weighting the information from path physiological measurements according to the clinical skill.

Therefore, in the pro- posed approach, once the optimal weight parameters are found by means of the PSO procedure explained in the last section, the medical prognostic process is modeled by means of the sum of the information from depending on suitable weights.



Membership functions of the Fuzzy sets:
a) Forced expiratory volume,
b) six-minute walking test,
c) MMRC dyspnea scale, and
d) body mass index.

The proposed procedure



4. EXPERIMENTAL RESULTS

The proposed method of automatic prognosis was validated experimentally in comparison with both a well-known prognosis criterion and a traditional statistical analysis. In the following, details about (i) the clinical case study, (ii) the validation by GOLD criteria, and (iii) the quality analysis of the proposed algorithm are given.

A. Clinical Case Study

The method was tested on a clinical data set of 63 patients (age), affected by a moderate to severe COPD admitted in the Rehabilitation Institute of the Foundation Maugeri of Telese Terme (BN, Italy).

All subjects underwent a monthly follow-up for 1 year by a noninvasive physiological monitoring of the following 4 clinical parameters:

1) Forced expiratory volume (FEV1%), expressed as percentage of a maximum value assessed by a spirometry test in 1 second;

2) Six-Minute walking test (6MWT), a simple stress test, namely consisting in the meters walked in six minutes;

TABLE 1

COPD CRITICALLY INDEX

Criticality index		kg/cm^2
I Low	FEV1/FVC< 0.7	FEV1> 80%
II Moderate	FEV1/FVC< 0.7	50%<FEV1< 80%
III High	FEV1/FVC< 0.7	30%<FEV1< 50%
IV Severe	FEV1/FVC< 0.7	FEV1< 30%

B. Validation by Gold Criteria

The proposed algorithm was validated by comparing its prognosis with the well-acclaimed criteria GOLD [24]. They permit to define if a patient is moving towards a critical respiratory condition. Further work is devoted to validate this approach on diseases other than COPD, and with a greater number of physiological parameters to be optimized. The risk is classified on the basis of the single FEV1 and FVC values monitored at each point in time.

5. CONCLUSION

A method to predict a critical condition of a patient, affected by a specific disease, at an early stage and in absence of clini- cian, based on swarm intelligence optimization procedure, has been proposed and tested experimentally. The proposed method turns out be useful to home health monitoring systems, where some physiological parameters related to a specific disease are being monitored.

Experimental validation showed the capability of the method of achieving an early prognosis with a high accuracy level.

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