Personal Diabetes Management Tools based on hybrid Neural Nets

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Abstract

In the last years we developed and tested a special software tool for personalized diabetes management. On basis of a large range of filled questionnaires from American and German diabetes patients we trained special neural nets to create a personal finger print for each patient to enable an individual therapeutically support and guaranty a continuous monitoring over time. Especially our categorizers differ between social, educational and ethnic background and, based on a class oriented four level statistic, the states of the patients factoring the different psychological, physiological, familiar and social factors. In such way our system leads to a supervision and guiding system for patients and the attending physicians and guarantees an over all cost reduction of factor 5 - 7.

1 Introduction

Diabetes (diabetes mellitus) describes a group of metabolic diseases in which a person has high blood glucose, either because insulin production is inadequate, or because the body's cells do not respond properly to insulin, or both. Diabetes can be divided in two forms: Diabetes Type I and Diabetes Type II.

As both forms differ, every diabetes management system also has to distinguish both groups generally, as same as (general) cultural, sociological and familiar background together with the attitude of the patient regarding this form of disease [2],[3]. It is this enumeration of fundamental different parameters which leads to the finding that common expert system or simple software are unable to handle all different parameters in the necessary context of an individual handling of the patients' disease.

Rather, it is necessary to use new algorithm to combine all the different parameters and - out of them - to form an individual personal finger print of the patients' behaviour and the medical treatment for effective supervision and therapeutically guidance. Such algorithmic structures can be realized by using the methods and procedures of the so called computer-based intelligence (CI) as on one hand the CI enables scientist and applicants to categorize diffuse or incomplete data sets by self learning algorithm, on the other hand the CI enables to combine information automatically from unequal sources and formats. In so far, CI can be seen in the context of Big Data and Data Warehouse too.

2 Methods

2.1 Basis Modules of the System

Our personal diabetes management system consists of four different basis modules:

- Data Base Module (DB), storing all questionnaires and their corresponding answers, personal data, trends, neural net structures and labels for the different country versions.
- Online and Printing Module (OPM), enabling the connection to the World Wide Web, the mailing function, the report generator and the communication to the printer equipment of doctor's office.
- The Graphical User Interface Software (GUI), enabling the Man-Machine-Interaction (Patient to Computer Dialog, PCD), the help functions and the choice of the individual language of the country where the system is momentary used.
- The CI-Module, involving the neural net structures, the special categorization algorithm, the learning procedures for the system and the evaluation and visualization modules for testing on confidence.

All these modules are running combined in background, where the system itself has the following three main working modes:

- Patients' Mode (PM)
- Doctors' Mode (DM)
- Maintenance Mode (MM)

2.2 Basis Functionalities of the System

To ensure that data security is given, every patient and the doctor's office personal stuff have a 9 letter password, which ensure the patient (and doctor) to see all personal data the results of all questionnaires and trend analysis results only. Furthermore the doctor and/or the doctor's office stuff is able to create new patient's "cards", means new patients, stored in the data base.

If a new patient's card is created, first all necessary personal data are evaluated by an interactive PCD-dispute, where the systems check all data on logic and completeness. In the second step the patient is lead through the questionnaire. In our system this questionnaire is divided in 10 logical categories. This enable to analyse different items of patients' life and behaviour. These categorise are

disease status and history physical, psychological, social and familiar status, self and foreign assessment.

After a patient has answered all questions (or optional one or more categories) the system categorises the patient via its neural network structure. On demand these categorisation results can be posted to the doctor's office and/or to the patient via internet and/or mobile devices, where the results are bundled in pdf-reports.
In the doctors mode the system can be conditioned, means special neural nets can be created and trained. Furthermore in this modus the doctor is able to create a statistical- and neural- overview of all his patient data together.

2.3 Principle of the Neural Net Based Categorizer

Surely the core of the system can be found in the neural network structure, which is the underlying data analysis algorithm of the personal diabetes management system. Therefore we explain here some basics of these CI-oriented methods. Neural net are more or less a simulation algorithm of central nervous functionalities. Therefore they can be divided in several neurons, which are combined via synaptic connections. These connections can be conditioned in a special training modus. The training it self can be done in two modes: supervised and unsupervised. Supervised training can be done easily if one knows everything about the system to be categorised and examples of all possible states of the system are know. As we don't know, how many different classes of patient or (different) states of the disease are existent this method is not sufficient for a diabetes managing system.
As a result, for our intention the second method to train a network - the unsupervised training - is more sufficient. If this learning method is used, the fundamental algorithm separates all categories of the data, presented to the net during the training phase by itself. Unfortunately with common self organizing neural nets this proceeding leads to a well known problem: At least for every different state of the system/patient, one single neuron has to be implemented, or - if we don't know how many states exist - more neurons then existing states have to be implemented in the network. To work around this principle bottleneck, we developed a new kind of processing and interpretation strategy of these nets, called "Computing with Activities" (CWA-Method) [1]. Out of this theory, we don't interpret the activity of a single neuron, but the overall activity structure of the whole net. We are sure that this interpretation is near by the neurological assumption, that neuron ensembles activity pattern represents different items like objects or minds of the cortex and an example will show, how powerful this new theory is: Following the classical information theory of the simulated neural nets we can store in a 200 neurons containing net 200 different states of a system/patient. But if we use the CWA-Method and define that our simulated neurons can assume five different states (such like five different firing modes over a fixed time interval) we can store and code 5^{200} states of a system/patient in the same net. This is more information as all films ever produced together!
Beneath this nearly unlimited storing volume, the CWA-method also ensures that slightly changes in the data sets lead to slightly changes in the categorisation result too and vice versa; means by CWA great differences in patient states lead to great differences in the activity pattern of our basic categorisation results and vice versa. Images 1a and 1b show some examples of such an activity based categoriser. The upper examples show a small difference in the data sets, the lower a bigger difference. It is important to mention, that the data sets used have the dimension of 20, means 20 parameters (here 20 different answers to 20 different questions) have been combined to categorise different patients regarding their similarity in behaviour and status.

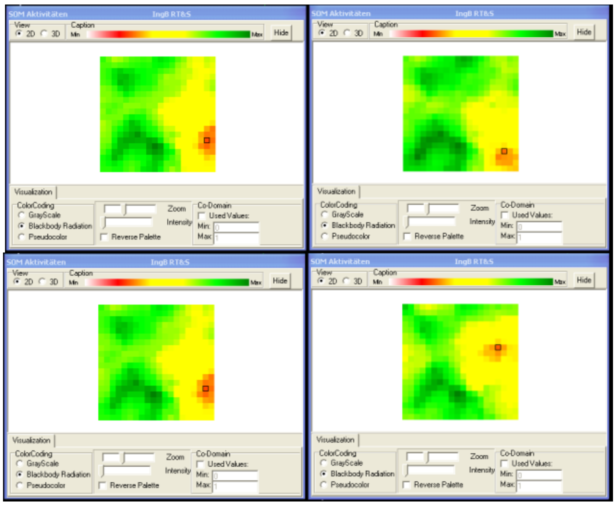

Image 1a/1b CWA-Method explained by similar patients and unequal patients categorization

2.4 Categorizations criteria and trend analysis

Once a patient has answered all questions the neural net structure categorizes the patient as described before. Needless to say that our system needs an adequate machine-user-interface which enables to interpret the neural based categorization in intuitive and quick way. For that reason we implement a special interpretation module, which analyze the neural activity pattern in that way that four different general categorization classes are describing the momentary states of a patient. These classes are combined with a kind of "to do list", means containing a reference of therapeutic interventions. In detail these categories and therapeutic interventions are:

- Green: patient's state is ok, non action is needed
- Yellow: patient's state is more or less ok, but has to be supervised and improved
- Orange: patient's sate is not ok, action is needed
- Red: patient's state is alarming, prompt action is needed

In that way the doctor/medical stuff at least have a tool which enables the inquiry of the patient's state via a simple (quick) view, as exemplified by Image 2
The neural based personal diabetes management system includes three different levels of patient evaluation as shown in Image 2, too. First of all - represented by the left hand side block - the overall state of the patient is visualised. In Image 2 everything is ok, indicated by the green colour of the three columns of the left hand side

block. The block in the middle shows the patients trend over time. In the left hand sided column a yellow categorisation is shown, the middle and the right hand sided columns show a green categorisation. We use these three different categorisations to evaluate, which kind of categorisation fits the real state of a patient best.

In detail the left columns of each block point out the average of the analysis of all data (here the over all analysis and the trend analysis of the patient's data), the middle column represents the neural net categorisation of the states following the four classes: green-yellow-orange-red.

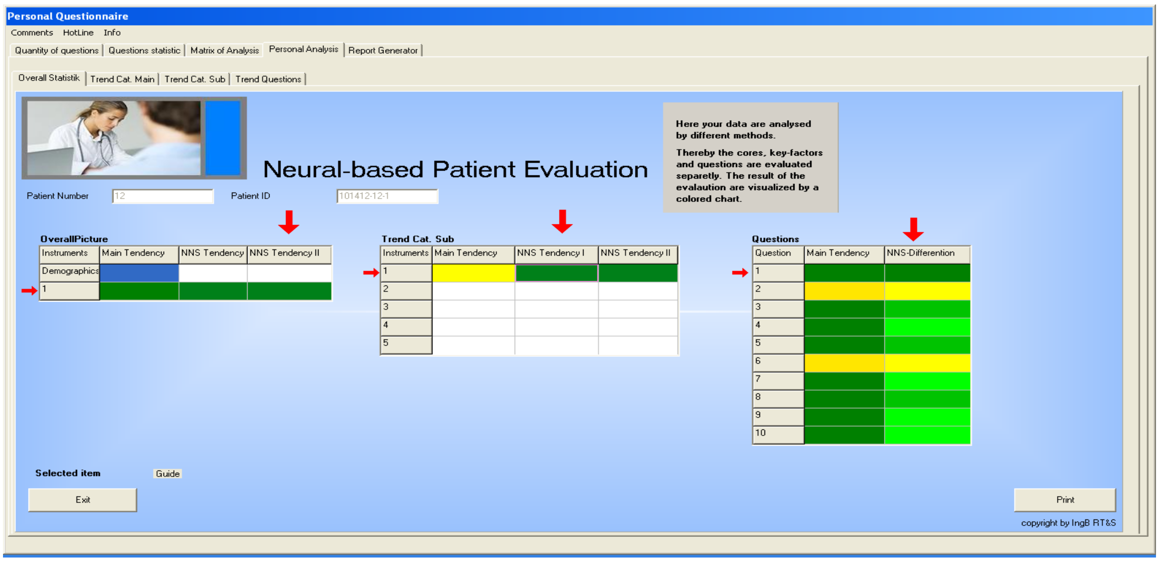

Image 2 Color-coded patient state analysis

At least the right column represents the categorisation of the neural nets by corresponding rainbow colours. Surely the rainbow colour representation of a patient's state is more significant than all other representations, but for a quick overview it is helpful if a categorisation of our fixed four colours is presented for reference too. This argument can be pointed out more clearly on hand of the categorisation of the single questions (right hand side block). In this block on the left hand side the traditional four colours coding is shown, the right column shows the categorisation by the corresponding rainbow colours. As our investigations show the chosen colour coding enables a more detailed analysis of patients within "one view", where especially the break down from the global categorisation of the over all state of the patient to the single questions leads to an effective (adequate) estimation of diabetes management.

The overview of Image 2 describes only the momentary status of a patient. To ensure that therapeutic treatments are successful over the time, or to identify deteriorations on one or several areas, we implement a statistical module which analyses the categorisation results over the time. Based on the database entries of the patients, this module identifies three different trends – again on basis of our colour coding – and visualise them in special charts, as exemplary shown in Image 3. Out of this charts another module calculates a trend prognosis, where statistical blips are taken into account (neglected) too. Furthermore different time intervals for the trend prognosis can be chosen, which gives the medical stuff the opportunity, to analyse momentary and longsome changes. Moreover the medical stuff or the patient itself can choose alternatively the categorisation of the global status or the categorisation of the single questions. In that way our tools enables to indentify the weak or the strong points in patient's behaviour and/ or patients handling of the disease. At least by the methods and trends we described, the doctors, the medical stuff, the social environment and the patient itself are empowered to supervise and interpret the momentary and past states of the patient/the diabetes running.

In detail Image 3 shows the chart of the colour coded categorisations of the blood glucose control of a patient over 20 examinations (left hand side). Easily it can be pointed out, that at the beginning of the examinations the values have been very low, than improved and at least get worse again. The middle block shows – again colour coded – the statistical parameters, here the centre of gravity (means the overall middle value), the FactorK, which is a prognosis for the next weeks and the momentary trend over the next 10 days. At least our tool contains a report generator, enabling to archive the categorisation results and trend analysis charts in Word or pdf-documents. The documents generated by the report generator, can be stored in an anonymous or personalized form, can be printed out directly and/or be sent via email to the patient or a medical centre. Furthermore the report generator enables the doctor and/or the patient to select further examination results for printing and/or controlling. A standard form of a report is shown in Image 5. At the top of the report the personal data are (optional) given, followed by the legend of the color coding. Next the different questions text and their classical and neural based categorization results are listed. The report of the questions ends with the chart of the completed questionnaires and the long and short time prognosis, coded again by three colors and a short text segment.

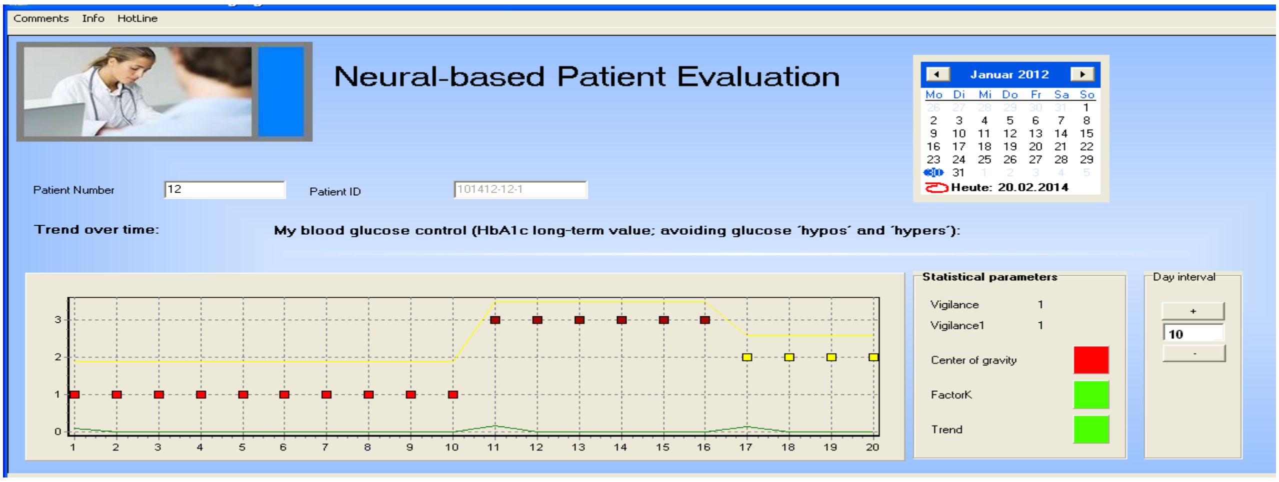

Image3 Trend analysis and trend visualization of a patient over 20 examinations

The patient personal data are collected by a standard user interface.

3 Results

We condition and test the system with two different data sets to explore the data sets of the partner company SMO Networks, which also provided the questionnaires. The first data set, collected in the USA, contained 1024 patient's questionnaires data, 501 of Diabetes Type I and 523 of Diabetes Type II. The second data set, collected in Germany, contains 612 patient's questionnaires data of Diabetes Type I and 564 of Diabetes Type II. Different social, ethnic and educational groups have been recorded to empower the neural nets to differ adequate between the wide ranges of data. After the training phase of the neural nets, the statistical distribution of the categorized data sets were evaluated and compared with literature to ensure our system reflects reality. Image 9 shows a net, based on a well balanced data set. Next we evaluate the final system regarding its "safe time"-factor; means, we asked test persons to supervise and assess patients by common methods like (paper or computer based) patient's medical files, Excel data sheets or conversation and by using our system.

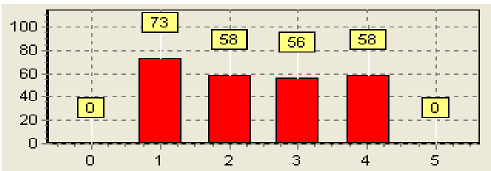

Image9 Balanced statistical distribution of patients data.

After a short training phase, our test personal needed a factor ten less time for a patient evaluation; means the system enables a cost savings of more or less factor seven.

4 Conclusion

We presented a computer- and computer-intelligence based system for Diabetes management and patient trend analysis. Core of this system are small effective neural networks, trained by patient data of different social, ethnic and disease-related environments. Due to its structure, the system can be continuously adapted and sensitized by means of new data. In that way over time regional influences are incorporated automatically into the systems behavior, reps. into the systems categorization behavior.

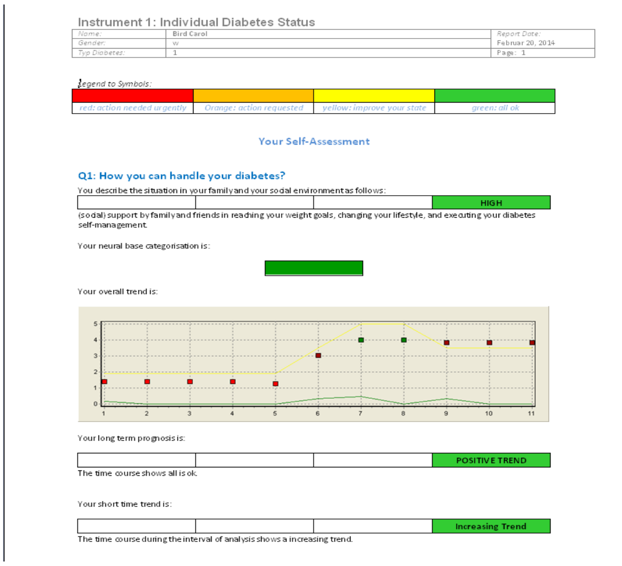

Image5 Report of an exemplary patient categorization

5 References

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