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THE NEUROLOGICAL DISEASE CLASSIFICATION BY MEANS OF ITS SINGLE DESCRIPTORS COVERAGE FINDING

The reported diagnosis supporting system was provided with knowledge base determined by the disease characteristic features descriptors that were recorded in conclusions table. Every descriptor defines the elementary rules related to every disease factor threshold value, recognised as a sign of the disease presence (the over-gone physiological state). The introduced definitions of the disease characteristics and some fuzzy logic proposals implementations were defined for the decision making system development.

1. INTRODUCTION

Gait abnormalities are a visible factor of neurological disorders recognition process, a single component in final diagnosis [1], [2]. Some differences from physiological, so called normal state are expected to be distinguished. The carried out investigations concern characteristic differences of a current data record, as: patient posture description, body balance trajectories and gait stability evidences, over-going time-range norms, a step length measures, footprints on standing (static) and walking (dynamic) cycles [3], [4].

The diagnosis unit operator needs some indicators, providing him with description and all measures of the gait abnormalities with its differences from physiological states. In many clinical practices a proper recognition of the above characteristic features was possible in time of traditional; neurological investigations. Anyhow, several diseases with their specific cases (ex. early Parkinson's disease state) were found [5], [6]. The disorders of their gait characteristics were appointed as the only observable diagnosis factors that were recognised as a unique possibility of establishing the diagnosis automatically [7], [8].

The gait characteristics classification, with their specific measures definition, will give the user the aim of diagnostics, therapy (rehabilitation, pharmacotherapy) controlling and the disease level judgment.

The carried out clinical experiments, organised by very experienced stuff, were fundaments to the classification procedures, discussed in this contribution. The example diagnostics, used at clinical scale, concern a main state of the patient's health recognition. The classical measures were noticed as undoubtedly defined, generally for the stroke

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(*Scandinavian Neurological Stroke Scale*), recognition level. Their gate disturbances were assigned by very primitive five points scale classes only [6].

Instead of putting the diagnosis on a full range data, single characteristic features were distinguished. Fig. 1 illustrates the example of body balance disturbances.

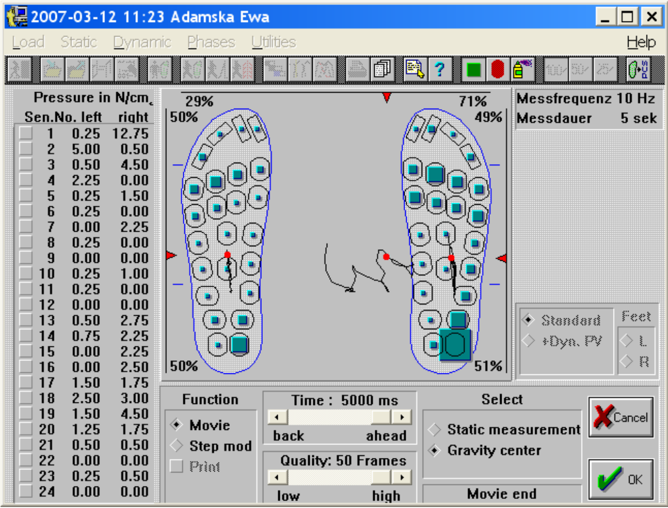

Fig.1. An example of patient body balance disturbances

On this illustration one can find the example measures of the body balance disorders. Let MBC, describes the body balance measure disturbances, contained in a static record part that can be noticed as characteristic measure for several neurological diseases. WRNX expresses the pressure (the load) distribution factors, where X, concerns the patient body posture leaning descriptor; in standing.

For this conclusion processes some relations R_i can be defined:

R1: *MBC>"medium" & WRNX<"medium"*- (for a left sided body load) or R1*: MBC>"medium" & WRNX>"medium"* - (for a right sided body load) are checked.

Patients affected by cerebral stroke, are suffering from right-sided hemiparesis. Their walking trajectories (Fig.2) are remarkable longer on the paresis side (and visible shorter on not affected body side). The affected limb is moving from heel to toes irregularly that is visible as trajectories elongation, with disturbances at 1st and 2nd [3] step phases. The Parkinson's disease indications concern bilateral fluctuations (tremor) of a load, dominated at an affected side. These appointed and other gait disturbing, separate features [8] bring us some distinguishable measures, describing all abnormalities.

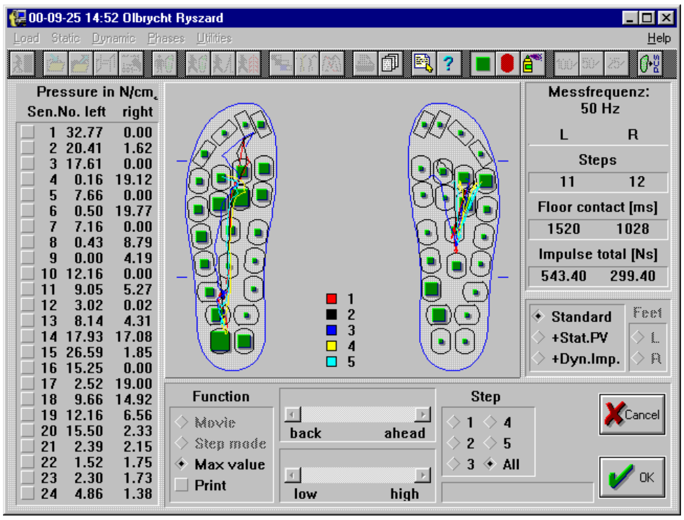

Fig.2. Right-sided hemiparesis after cerebral stroke

These specific measures are recorded by relations:

R1:MWRSCLX<"medium" and *R1:MWRSCPX<"medium"* – define the pressure centre location on left and right foot; respectively.

MWRSCLX – is a relative measure of body centre dislocation of a left foot. *X* defines a distance between maximal and minimal values of the *MWRSCLX.*

SOME TIME RELATIONS

The average times of start, support and push-off phases can also be treated as coefficients to step phases' time analysis (Fig.3).

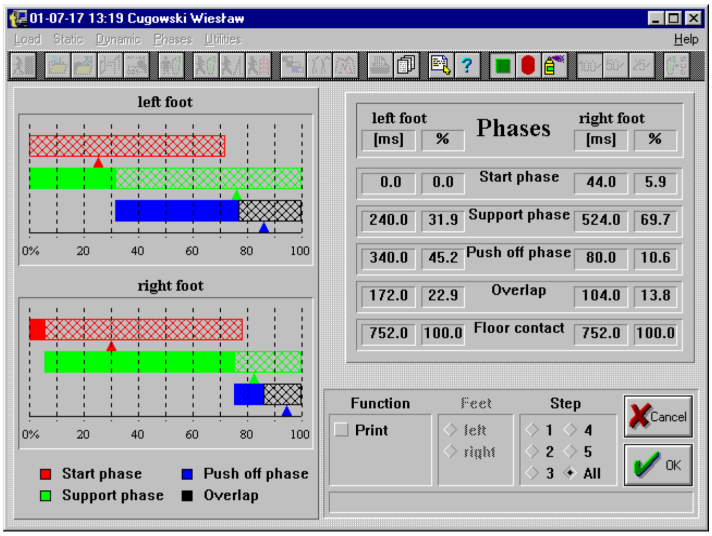

Fig.3. The gait phases example of Parkinson's disease

The start phase, describes the initial period of the step, where the body weight goes through the heel. Then the second foot is usually in push-off phase. The support phase shows a period of step, in which a body weight goes through the heel and metatarsus (as in Fig.1). In the push-off phase the body weight goes across toes, when the second foot begins its start phase.

Further investigations are illustrated by an example of relations finding for Parkinson's disease; functional disturbances (Fig.3).

The clinical observations indicate [4] some visible disorders, as:

- the body balance displacement,
- overload on the affected limb, mainly on a hill region,
- the body gravity centre and the load of the affected limb moving irregularly,
- elongations of gait gravity displacement trajectories (longer step of the affected limb),
- visible energy absorption on the affected side (within the hill region), is noticed.; when the not affected limb is carrying a main load within metatarsus.

2. THE CONCLUSIONS MAKING BASED ON GATE SINGLE DESCRIPTORS

The diagnosis support system was provided by knowledge database that was created under specific descriptors classifiers; working as the disease characteristic factors. They allow defining the decisions table, where elementary decision rules are set into. Every value in this table has its relation to the disease characteristic feature, with its value that is set to the expected threshold level; above which the physiological state is over-gone.

The introduced definitions have their direct relations to classical diagnostics approaches, making the conclusions by:

- natural expression of the disease unit with its elementary components (characteristic features) of the unit, with possibility of multi - components of the disease definition finding,
- formal interpretation of the diagnosis state, with its balanced clear explanation,
- possibility of the database knowledge permanent increasing, by new defined disease units and characteristics, also by previously defined elementary descriptors,
- modular idea of knowledge allowing us using the previously introduced rules, for further concurrent definitions, using the previously defined disease units,
- grouping some rules for the disease complex states appointment (different for every disease).

The conclusion rules are defined, as in every decision making system, by

$$T=<X, A, V, \delta>$$

where:

T – defines the decision table content,

X – is an objects set (at the table); its universe,

A – C∨D, defines a set of attributes, conditional and decision making;

C – is a set of conditional attributes,

D – is a set of decisions attributes.

Each object in the decision table is assigned by its specific descriptor. For pathology assignment, the parameter C illustrates the relation of the function product, with its measure

DM (for specified pathological feature) to physiological (starting) condition D. This expresses the level of the disease.

V – is a set of attributes values, adequate to the disease level, being under consideration.

δ: X × C → V_d – expresses Cartesians multiplication of the table members with their conditional attributes. This is equal (in majority cases) *False* or *True* of the decision making attributes, in the conclusion function.

C – representing the set of starting conditions (physiological states),

D – defining the set of diseases; classes; groups or the disease units.

Then the correlations for the decisions will be found from:

δ: X × C → (D, V_i) – the correlation function of the disease and its characteristics feature; being a pair of values defined by the Cartesian multiplication of the rule and the conclusion condition. This will appoint the decision relevant attributes.

The implementation of these rules allows us using two values of the decision only, with fuzzy defined attributes. Their values are defined by V_d <0..1>.

The conclusions conditions were written by a set of linguistic values, as:

{ V_i }={„very small”, „small”, „medium”, „big”, „very big”}

The conclusion unit analyses the above conditions and given relations, specifying the disease stage (advanced pathology or indicating the disease factors presence).

3. THE EXAMPLE SOLUTION OF THE CONCLUSION

In Fig 4 an example interpretation of the conclusion functions, with its measure DM $(\text{table1})_x$ was introduced. Let the smallest threshold of the decision level was set into 0,05 and the biggest one is equal to 0,07.

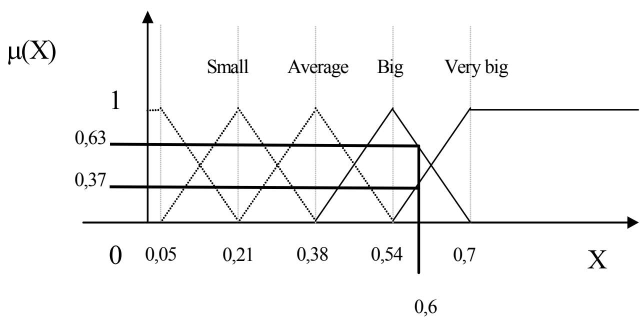

Fig.4. Principle of membership factor declaration *μ(x)* for some linguistic notions

When the current record produces the data 0,06, one can find at least 7 disease units fulfilling the given threshold relations; in <0..1> range. This conclusion has to be distinguished by additional analysis that allows indicating other features of the disease. What is more, the range of the smallest and the highest conditions values have to be considered very carefully. The classification vales were defined in fuzzy terms of the output values. The decision formal approach was based on none contextual grammar relations, G:

$$G = <N, \Sigma, P, S>$$

G – the none contextual grammar sphere,
N – the set of interminable symbols; the additional alphabet,
Σ – the set of terminable symbols; the final alphabet,
P – products list,
S – the grammar and axiomatic head .

The set of interminable symbols was written as:

$$N = \{V_m, V_r, V_i, \&\}$$

Where: **Σ** = {R, W}
R – is a rule
W – condition

Products:

$$\boldsymbol{P}: <W> ::= V_{m_i}\ V_{r_i}\ V_{i_i}$$

The condition can be assigned by the relations of the measures {„<”, „>”} and by their linguistic expressions:

{very small, small, medium, big, very big}

Example: Let us assume that *WRNX* < very small

Then relations: $<R> ::= <W_1> \mid <W_1>\&<W_2> \mid <W_1>\&<W_2>\&<W_3>$

The grammar head **S**=W describes the condition supported by three sets, as it was introduced bellow:

V_m = *{the measures abbreviations in DM table}*

V_r = *{relations „<”, „>”}*

V_i = {linguistic values: very small, small, medium, big, very big}

For the conclusion unit implementation the products of the defined grammar create one to three starting conditions that are joined together by conjunction operator, where the rules, with the same identifier, are treated as a set of rules joined together by alternative operator. They assign the same disease unit

For this knowledge database creation 69 of diagnostic factors, with their measures, were distinguished and implemented. They can be divided into three groups that are describing:

- the limbs overload and body balancing measures in time of standing (a static data)
- the gait stability with start, support and push-off phases description,
- maximal and minimal load on the patient's feet, with pressing energy absorption within the three zones of the foot.

After clinical observations and experts' comments two rules for left-sided and for right-sided hemiparesis were extracted, used for the diseases identification. The investigated measures describe conditions for brain stroke classification. From 69 records, 10 were recognised as a stroke.

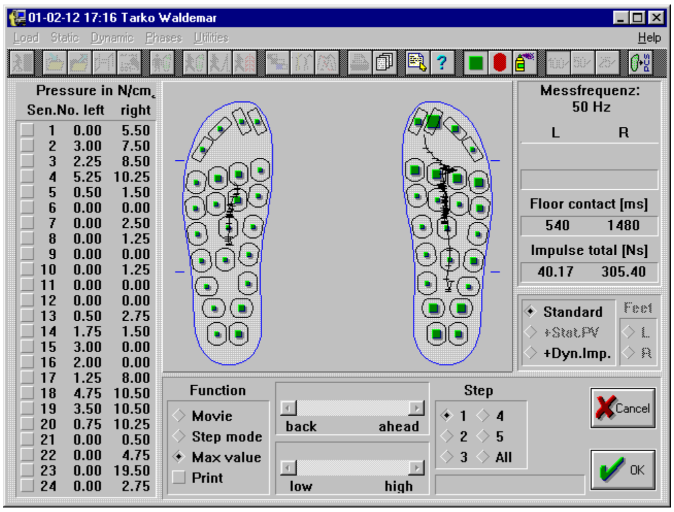

Fig.5. The right-sided hemiparesis example impulses

Various visualisation interfaces provide the user with diagnostics measures (DM):

- the body load transfer from back to front side of a foot and between left / right limb (in standing period).
- a pressure distribution in three zones of a foot (heel, front, metatarsus) and a body load distribution between both limbs; left / right (in walking phase).

Table 1. Example Diagnostic Measures - DM

Functions	Measures definition
WFWKL	**Push-off phase on a left step** *Defining a medium value of the push-off step phase duration time, at a left limb*
WFWKP	**Push-off phase on a right step** *Defining a medium value of the push-off step phase duration time, at a right limb*
MSRNPIL	**Static pressure distribution on a hill region of a left foot** *Defining pressure values in static data part (in standing)*
MSRNPIP	**Static pressure distribution on a hill region of a right foot** *Defining pressure values in static data part (in standing)*
MRISSB	**Impulse distribution measures on metatarsus external part on a left foot** *Medium strength (energy) in specified zone of a left foot in walking cycle*
MRISSSL	**Impulse distribution measures on metatarsus internal part on a left foot** *Medium strength (energy) in specified zone of a left foot in walking cycle*
MRIPIL	**Impulse distribution measures on a hill zone on a left foot** *Medium strength (energy) in specified zone of a left foot in walking cycle*
MRISSBP	**Impulse distribution measures on metatarsus external part on a right foot** *Medium strength (energy) in specified zone of a right foot in walking cycle*

MRISSSP	**Impulse distribution measures on metatarsus internal part on a right** *Medium strength (energy) in specified zone of a left foot in walking cycle*
MRIPIP	**Impulse distribution measures on a hill zone on a right foot** *Medium strength (energy) in specified zone of a right foot in walking cycle*

The example measures can be used for diseases description, as:

Relation R1: (MSRNPIL > medium) & (WFWKL < small) → left sided hemiparesis
Conditions W1:(MSRNPIP > medium) → right sided hemiparesis
W2:(WFWKP < small) → right sided hemiparesis

Relation R2: (MSRNPIP > medium) & (WFWKP < small) → right sided hemiparesis
Conditions W1:(MRIPIL > medium) → left sided hemiparesis
W2.(MRISSBL > medium) → left sided hemiparesis
W3:(MRISSSL > medium) → left sided hemiparesis

Relation R3: (MRIPIL > medium) & (MRISSBL > medium) & (WRISSSL > medium) → left sided hemiparesis
Conditions W1:(MRIPIP > medium) → right sided hemiparesis
W2:(MRISSBP > medium) → right sided hemiparesis
W3:(MRISSSP > medium) → right sided hemiparesis

Relation R4: (MRIPIP > medium) & (MRISSBP > medium) & (WRISSSP > medium) → right sided hemiparesis
Conditions W1: (MSRNPIL > medium) → left-sided hemiparesis
W2: (WFWKL < small) → left-sided hemiparesis

The R1 and R3 relations coefficient superposition imply the disease class (the left sided hemiparesis) recognition.

4. FINAL CONCLUSIONS

The dislocation of a body gravity centre was introduced to clinical evaluations that concern conclusions based on the body balance disturbances. This sample analysis provided us with very essential conclusions of early Parkinson's disease diagnosis, anyhow more complex clinical investigations were undertaken. The gait disturbances that come from neurological reasons are estimated in final diagnosis proportions. They offer many quantitative descriptions with their introductions into further clinical practices.

The simple formulas allow us continuous development of the data base knowledge on further clinical investigations; for neural networks conclusion making systems development [7], [8]. For these works medical stuff with simple capabilities in computer handling, can be used. Anyhow, the user has to know various threshold values (physiological level or other comparison levels) that have to be established by best specialists. Although the gait descriptors permit putting some restrictive diagnostic procedures the final recognition methods of the disease are still under development.

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