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Applications of fitness function in Pubalgia affliction

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Abstract

Introduction. The relationships among variables are important in medicine and sport, and the most common approaches use linear correlation for optimization and prediction. **Material and method**. We propose to o novel usage of a known method (the genetic programming algorithm) to construct a nonlinear model in a practical case for rehabilitation find out the mathematical formula for a relationship among many variables . This study seeks to find a mathematical function to estimate the current state of the patient: healthy, affected by Pubalgia. **Results and discussions**. In the proposed application, a mathematical relationship is sought for five variables that express a state of health for patients, plantar footprint, plantar footprint – right, plantar pressure, plantar pressure – right and the surface of the body weight center. **Conclusions**. In this article, genetic programming has been proposed to construct a mathematical function to estimate the patient's condition possibly affected by Pubalgia.

Keywords: *e-health, rehabilitation, genetic algorithm,fitness function,*

Introduction

Linear regression and multiple linear regression (bivariate or multivariate) are used for modeling the relationship between variable (usually a scalar) and more explanatory variables (independent variables or correlated variables) in many areas of research and practical applications. The correlation used is linear that is the variables are testes if they are correlated linearly. If the correlation test has the value zero, this means that the variables are correlated linearly but no information is given about the possible nonlinear correlation. The nonlinear correlation is difficult to be discovered and the most common proposal is based on heuristics: the polynomial form or exponential form. If these approaches give no satisfactory results, no systematic method has been proposed in the medicine and sport and not only.There are studies that deal with relationship between or among variable but no mathematical formula is given in order for this relationship (1,2,3,4,5). The most common approach is the linear one, where a linear regression is used to discover the linear relationship, as in (5,6,7,8,9). Very few paper deal with nonlinear relationship in the area of medicine or/and sport, one of them is (10) , where a polynomial of degree two ($y = a + bx + cx^2$) is proposed as nonlinear model (along with a linear model, $y = a + bx$) between anthropometric measures and the motor-endurance status. Recent paper suggests that nonlinear model are better but no practical example is given (10). Pubis osteitis is a non-infectious inflammation of pubic symphysis. It was first described in 1924 as a complication of surgical interventions performed above pubic symphysis, but it was later found that this condition also occurs as an inflammatory process in athletes causing pain in the insertion of abdominal muscles and at the level the pubic symphysis joint. The main symptoms experienced by athlete affected by the pubis osteitis are decreased joint mobility, pain in the inguinal region, exacerbated pain in running, stroke of the ball, directional change or even during routine activities such as car climbing, walking, climbing stairs or even in the position of orthostatism. A method to construct a mathematical function that can estimate the current state of the patient (practical an e-health index) based on experimental non-invasive measurement over patient is proposed.

The method use the genetic programming techniques and three qualitative levels of patients’ affection by Pubalgia : healthy, affected by pubis osteitis or tendency towards normalization. The results were with good results for experimental data and other improvements are in progress. Pubis osteitis is a non-infectious inflammation of pubic symphysis (12). It was first described in 1924 as a complication of surgical interventions performed above pubic symphysis, but it was later found that this condition also occurs as an inflammatory process in athletes causing pain in the insertion of abdominal muscles and at the level the pubic symphysis joint. The main symptoms experienced by athlete affected by the pubis osteitis are decreased joint mobility, pain in the inguinal region, exacerbated pain in running, stroke of the ball, directional change or even during routine activities such as car climbing, walking, climbing stairs or even in the position of orthostatism. Specialty studies have shown that the main causes that may cause puberty osteitis are:

- Sports activities (example: football, hockey, tennis);
- Minor repetitive trauma (specific to sports activities);
- Major trauma;
- Surgery (gynecological or urological);
- Rheumatologic disorders

A method to construct a mathematical function that can estimate the current state of the patient (practical an e-health index) based on experimental non-invasive measurements over patient is proposed. The method use the genetic programming techniques (13) and three qualitative levels of patients' affection by Pubalgia : healthy, affected by pubis osteitis (14,15,16,17) or tendency towards normalization. The results were with good results for experimental data and other improvements are in progress

Matherial and Methods

The study was conducted on a number of 35 subjects, of which 30 healthy subjects and 5 affected by pubalgia (pubis osteitis) . All subjects had the weight between 60 and 90 kg, the size between 170 and 190 cm, the plantar size ranging from 22.5 to 28.5 cm and the age between 20 and 30 years. All 35 subjects were evaluated with a Pedro OEM / DF Postrotest, and at the end of the evaluation, plantar imprint, plantar pressure, and general weight center were collected. Anthropometric development assessment was used to select subjects, resulting in better control of variables.

We used:- An electronic scale "SilverCrest" model "SPWS 180 B2" manufactured on 12.2013. in order to measure the weight in the range of 60-90 kg;

- A Wunder marker for measuring the waist in the range 170-190 cm;
- Metric band (centimeter) with gradient from 1 cm to 150 cm. in order to measure the planting size in the range 22.5 - 28.5 cm.

Post-urology-stabilometry are new methods of investigation used both for establishing the clinical and differential diagnosis and for following the evolution of these disorders, being considered non-invasive methods. A posturotest with the operating system was used to perform the pilot research: OEM / DF PEDAN, DISP MED. CLASSE I "since 2007.

Subjects tested by posturotest were trained and informed as follows:

- on the next test;
- on board the platform;
- on the movements they can perform once they are on the posturotest (they must remain motionless until the therapist's signal and follow a point on the wall located perpendicular to the visual ray);
- on the equipment (shoe and barefoot);

Subjects affected by puberty (osteitis of the pubic), in number 5, received rehabilitative treatment (8). Rehabilitation treatment was lasting for 4 weeks (20 sessions), each session lasting 50-70 minutes and was composed of massage techniques, PNF techniques, stretching and therapeutic physical exercises.

The treatment session for each individual was structured as follows:

• Massage (smoothing and friction) - duration of 5-10 minutes;
• Stretching (passive) - duration 5-10 minutes;
• Massage (smoothing and friction) - duration of 5-10 minutes;
• Muscle proprioceptive neuromuscular facilitation (relaxing opposition and slow inversion with opposition) - duration 5-10 minutes;
• Massage (smoothing and friction) - 5-10 minutes,
• Stretching combination with proprioceptive neuromuscular facilitation techniques - 5-10 minutes duration,
• Massage (vibration) - duration of 5-10 minutes.

Dosage consisted in varying the duration of each technique used, depending on the individual's motor skills, stage, pain. This study seeks to find a mathematical function to estimate the current state of the patient: healthy, affected by Pubalgia or tendency towards normalization (treated). This function will be built on a number of five parameters

(Table I), such as: plantar footprint – left (PFl), plantar footprint – right (PFr), plantar pressure - left (PPl), plantar pressure – right (PPr) and the surface of the body weight center (Sbwc). In Table 1, we can see some of the 30 healthy subjects used in the study, and in Table 2, we identify the values of the 5 subjects affected by Pubalgia. Following the physical therapy treatment (performed over a four week period, 20 sessions), the subjects were retested and the data obtained can be seen in Table 3. In order to find this math function, we used the data from Tables 1, 2 and 3, but at the same time we used the genetic programming that are an evolutionary algorithms and include a set of individual elements represented in the form of binary strings, the so called population, and a set of biological operators defined on the population.

Table 1. Example of values from the 30 healthy subjects.

Subject	PFr (%)	PFl (%)	PPr (kgf)	PPl (kgf)	Sbwc
1.	41.8	58.2	32	18.8	0.28
2.	48.2	51.8	42.4	35.5	0.408
3.	33.7	66.3	23.5	12.9	0.323
4.	42.9	57.1	23	21.5	0.206
5.	46.5	53.5	27.2	22.6	0.2
6.	38.6	61.4	19.6	17.7	0.135
7.	36.1	63.9	37.5	24.6	0.157
8.	39.3	60.7	26.7	22.8	0.107
9.	43	57	38.4	31.6	0.204
10.	44.5	55.5	16.5	16.1	0.261
11	41.3	57.3	31.2	25.6	0.21
12	47.2	51.6	41.3	18.2	0.306
13	34.1	64.3	22.5	35.2	0.158
14	45.6	56.9	22.3	12.4	0.108
15	36.8	52.5	26.9	21.2	0.263
16	37.9	60.4	19.2	22.5	0.3
17	41.3	57.3	37.3	17.4	0.127
18	39.8	54.5	15.9	30.3	0.137
19	43.8	60.4	40,4	12.5	0.206
20	37.6	59.7	23.7	27.3	0.246
21	38.5	56.3	24.9	24.4	0.4
22	41.6	64.9	31.8	31.3	0.156
23	44.3	61.1	15.3	32.5	0.321
24	39.8	57.8	27.8	19.8	0.236
25	41.5	51.1	31.7	23.5	0.118
26	39.7	53.7	28.3	29.6	0.298
27	41.2	60.3	31.2	31.4	0.119
28	34.3	61.8	19.7	27.5	0.207
29	36.6	59.2	41.9	23.9	0.213
30	43.9	56.4	42.3	21.1	0.112

Legend: PFr = plantar footprint – right, PFl =plantar footprint – left , PPr = plantar pressure – right , plantar PPl = plantar pressure - left , Sbwc = surface of the body weight center

Table 2. Values from the 5 subjects affected by pubalgia (pubis osteitis).

Subject	PFr (%)	PFl (%)	PPr (kgf)	PPl (kgf)	Sbwc
1.	63.8	34.2	56.3	13.8	0.145
2.	68.4	31.6	60.1	14.5	0.121
3.	62.1	37.9	70.6	25.6	0.171
4.	67.8	32.2	51.3	24.9	0.125
5.	67.7	22.3	65.6	31.4	0.116

Legend: PFr = plantar footprint – right , PFl =plantar footprint – left , PPr = plantar pressure – right , plantar PPl = plantar pressure - left , Sbwc = surface of the body weight center

Table 3. Values from the 5 subjects that performed a physical therapy treatment.

Subject	PFr (%)	PFl (%)	PPr (kgf)	PPl (kgf)	Sbwc
1.	60.8	39.2	50.3	20.8	0.17
2.	61.4	38.6	55.1	15.5	0.161
3.	58.1	38.9	66.6	26.6	0.211
4.	66.8	32.2	50.3	24.9	0.139
5.	62.7	24.3	61.6	32.4	0.126

Legend: PFr = plantar footprint – right, PFl =plantar footprint – left , PPr = plantar pressure – right , plantar PPl = plantar pressure - left , Sbwc = surface of the body weight center

The scope of the study is to find out a nonlinear relationship between the variables noted by PFr – x_1, PFl – x_2, PPr – x_3, PPl – x_4 Sbwc –x_5 and a health index Ih – y, structured on three levels, as $y= g(x_1, x_2, x_3, x_4, x_5)$. The target values, health index are confirmed by three independent physicians. In our case, the application of this method produced an accuracy of (12%) , from complete set of values, a very poor result. This results show clearly that if we want to improve the accuracy of the model, a nonlinear solution is a feasible one. It is very hard to guess such formula and we chose a systematic method inspired by evolutionary algorithms, genetic programming.

Genetic programming use few new notations in addition with the known ones, used in Genetic programming. The terminals (T) are the variables used for modeling the functions, in our case $\{x_1, x_2, x_3, x_4, x_5\}$. The nodes are usually mathematical functions (exponential, sinus, logarithmic, power, etc.) or symbols of operations, as sum, subtracts, multiplication.

Results and Discussion

The genetic programming is an evolutionary method applied to a population of programs in order to achieve a predefined objective usually characterized by a fitness function (10).

The most common usage of fitness function is minimization of the objective function given by a fitness function. If the objective is maximization of the function $x_{fitness}$, simply we can consider the minimization of the function: $y_{fitnees} = -x_{fitness}$, the squares errors as goal of the genetic programming method. In our case, the error is given by the difference between desired value to be obtained by $\hat{y}$ function and the real value of y obtained by applying the formula of function. In genetic programming, the chromosomes are functions represented by trees in inverse Polish notation. The main steps in genetic programming algorithms are similar to evolutionary algorithms: selection, crossover and mutations. We must remark that all these genetic operators act on trees and sub-trees, different from other evolutionary algorithm where chromosomes are represented by linear sequence of genes. The main steps in genetic programming are described in what is following (11).

A first population of individuals is created using a random generator (usually uniform distribution). Each individual from population is evaluated according to fitness function. Using the fitness function, the selection operator selects the pairs of individuals (according to selection mechanism: roulette, tournament, stochastic sampling, etc.) in order to apply the crossover operator to create new individuals. The less performing individuals are discarded and the best individuals are grouped in a new generation. Mutations are performed in order to prevent the premature convergence and elitism disadvantages. The population is evaluated again and the loop continues until stop conditions are ful filled. The stop condition can be a predefined number of iterations or a number of steps (three or four generation) that cannot produce an improvement of fitness for the best individual from population.

In our application we are looking for a function of type:

$$F_{x,y,z,\,steel} = g(a_p, f_z, v_c) = \sum_{k=1}^{N_g} b_k \cdot g_k(a_p, f_z, v_c)\,. \qquad (1)$$

In order to compute g_k and b_k, $k = \overline{1,n}$ (n is the maximum number of genes) we use a set of terminals and operators (2):

$$T = \{a_p, f_z, v_c, RA\}, \qquad (2)$$

$$F = \{+, -, *, /, \exp, \text{power}\}. \qquad (3)$$

In terminal set, RA is a random value in the range [−10.0, +10.0]. In the proposed application, a mathematical relationship is sought for five variables $(x_1, x_2, x_3, x_4, x_5)$ that express a state of health for patients Y (healthy = 0.1, treated = 0.5, affected = 0.9): plantar footprint – left (PFl), plantar footprint – right (PFr), plantar pressure - left (PPl), plantar pressure – right (PPr) and the surface of the body weight center (Sbwc).

There are few software tools that are used for genetic programming: GPLAB, GP dot NET, GPTIPS, GP-OLS and also specialized software tools (Poly LX, texture analysis for petrol). An interesting extension of genetic programming is the combination of more genes represented by trees in a linear fashion and optimization of individuals in two stages: optimization of each gene and optimization of the linear combination (linear regression) (13). The optimal weights in linear model are obtained by ordinary least squares to regress the genes versus the output data (13).

In our application, we used the software *GPTIS* (10). Practically, the nonlinear model is modelled by a pseudo-linear model with nonlinear genes. A common measure of the degree of appreciation of a precision with which a function (of one or more variables) matches a set of experimental data, extrapolating and interpreting values, is $RMSE$ (root mean square of errors). The root-mean-square deviation ($RMSD$) or you can say root-mean-square error ($RMSE$) (or sometimes root-mean-squared error) is sometimes a used measure of the differences between data (sample and population values) predicted by a model or an estimator and the values actually observed. If a function $y = f(x_1, x_2, ..., x_n)$, then y_i, $i = \overline{1,n}$ the values obtained from n experimental samples and the value estimated by calculating the function f that analytically analyzes the process or phenomenon.

$$RMSD = \sqrt{\frac{\sum_{i=1}^{n} (\hat{y}_i - y_i)^2}{n}} \qquad (4)$$

With root-mean-square error car being closer to zero, the function found is an analytical mathematical model better for a phenomenon, process, or mathematical relationship. In general, a $RMSE$ <0.05 for a set of medical data is considered to be the result of a performance model. With root-mean-square error car being closer to zero, the function found is an analytical mathematical model better for a phenomenon, process, or mathematical relationship. In general, a $RMSE$ <0.05 for a set of medical data is considered to be an excellent result of a performance model. In our case $RMSE \approx 0.053$, a good results better than the linear model and in the row with best results from state of the art presented in introduction. The successful classification has a rate of (33*100)/35≈94.28%.

Conclusions

An evolutionary method, genetic programming was proposed to construct a mathematical function to estimate the state of the patient possible affected by Pubalgia . From 35 patients, only two cases were classified wrong, but the value of formulas was very close to the threshold between the classes. The further research will be conducted over a larger lot of patients and further refinement of the model expressed by mathematical function in order to have connections with physical phenomenon. This can be made by constraints over terminal and set of operators and possible depth of the trees. Also, more than three classes can be used in order to find a fine granulation of the e-health index value but this must be validated by medical assertion. The tool can be used as an automatic evaluator for monitoring the effectiveness of rehabilitation progress in treatment of Pubalgia and also as an evaluator of health after surgical intervention. The analysis of structural formulas can be used in the further research to evaluate the qualitative level of influence in health score of each variable. Depending on this value, some variables can be added to new analysis and other that have minor influence can be weighted with a lower value. It is also possible to eliminate some variables that have too lower influence in the evaluation of health process. In this way the clinical practice can be improved

Author contributions.

All the authors had the same contribution.

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