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NEUROMUSCLESCHELETIC ILLNESS IN MOVEMENT ISSUES FOR CEREBRAL PARALYSIS DETECTION SYSTEM

M. en C. Martha Rosa Cordero López, M. en C. Marco Antonio Dorantes González
Martínez Ruiz Fernando, Milla Vilchis Rodolfo
Escuela Superior de Cómputo I.P.N. México D.F.
Tel. 57-29-6000 ext. 52000 y 52021.
E-mail: marthac@mexico.com, mdorantesg@ipn.mx

ABSTRACT

The present project has a social focus, which pretends develop a system (hardware and software) capable to achieve a valuation of the neuromusclescheletic children's march, which is cerebral paralysis. This valuation will be done by several images, representing the march of the studied subject in a graphic way, to be compared with a normal march patron that will be evaluated by an expert who will determinate a proper treatment, witch will inhibit the low extremities' dominating muscles to improve the subject march.

Keywords- *Databases, Webcam, Software Engineering, Graphic Treatment, Pattern Recognition, Cerebral Paralysis, Neuromusclescheletic Illness.*

1. INTRODUCTION

1) *Cerebral paralysis.* On 1860's the English surgeon William Little wrote the firsts medical descriptions of a estrange disorder who used to attack the youngest children, causing muscle spasms and rigid legs and arms. This child has difficulty to grab objects, walk and crawl. Differing to the most of the cerebral diseases, this were doesn't get worst on time. Instead, the children's capacities remain the same.
   The disorder, called Little's disease for many years, now is known as spastic diplejía. It is a joint of disorders that affects the movement grouped in the "cerebral paralysis" term.
2) *The march*. One of the human's inner characteristics is the movement possibility on only two extremities way long on time. This fact is known as march. The march is a motion skill that gives great independence, when is affected by certain alterations on subject's health it origins many incapacity grades.

In a more specific definition, the march is a sequence of alternating and rhythmic movements in extremities and body that determine a forward movement of the person's gravity center with minimum energy waste.

The Normal Human March

The march is an action done by 3 segments of the body that act in coordination, the 2 inferior members and the pelvis.
Just like the locomotion of elder people, there is little documentation about the learning process of the march in a small child. Its normal to consider that at the age of 6 or 7 years old, the child has acquired the characteristics of the march of an adult, with differences of little meaning, linked to the difference in height such as: a higher cadence, lesser speed of the march, higher horizontal rotation of the pelvis and flexion of the hip. For its study a single cycle of the march has been identified.

The cycle of the march is the interval or sequence of movements that appear between two initial consecutive contacts of the same foot.

The development of the march cycle could be easily described by subdividing it in the following manner, given that for each foot the following consecutive events occur:

- Contact of the heel with the ground
- Full support with the sole of the foot
- Lifting of the heel or rear foot
- Lifting of the toes or front foot
- Oscillation of the member
- Next contact of the heel.
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2. METHODOLOGY

SiDePan is composed of eight modules, four of which are mainly tasked with the analysis of the march of the patient; session, taking of video, image processing and march evaluation. For us, a session is the moment in which the patient will start walking and the cameras begin to film it, the Session module is in charge of managing it. The *video taking* module is composed of three webcams. In this module the camera characteristics are adjusted as well, in real time, the displaying of such video. This video will be segmented I images for the *image processing* will undergo the following processes:

- March Phase Recognition

I.) Transformation to grayscale. In this step, the color image is transformed into a grayscale image

II.) Application of the Out threshold. The main problem of the binarization consists in finding the adequate threshold to minimize the loss of information. In the Otsu Method, an analysis of the histogram allows the dynamic determination of the optimal threshold for the image, applying the automatic selection method based on the histogram analysis.

As a starting point we take two segments of points (K0(t) y K1(t)) that will be defined according to the threshold value t. t is the variable we look for, and the two segments are the desired result in the segmentation.

Be p(g) the probability of occurrence of the gray value 0 < g < G (G is the maximum gray value). Then the probability of occurrence of the pixels on both segments is:

K_0: $$P_0(t) = \sum_{g=0}^{t} p(g)$$

K_1: $$P_1(t) = \sum_{g=t+1}^{G} p(g) = 1 - P_0(t)$$

If we take two segments (that is, a single threshold value) the sum of these two probabilities will evidently be 1.

If $\overline{g}$ is the arithmetic mean of the gray values of the entire image and $\overline{g_0}$ and $\overline{g_1}$ are the mean values within each segment then variances in each segment can be calculated, such as:

$$\sigma_0^2(t) = \sum_{g=0}^{t} (g - \overline{g_0})^2 p(g)$$

y

$$\sigma_1^2(t) = \sum_{g=t+1}^{G} (g - \overline{g_1})^2 p(g)$$

And

The goal is to keep the variance's value in each segment as small as possible and get the variance between the two segments as large as possible. That we get:

$$Q(t) = \frac{\sigma_{zw}^2(t)}{\sigma_{in}^2(t)}$$

The variance between the segments is:

$$\sigma_{zw}^2(t) = P_0(t) \cdot (\overline{g_0} - \overline{g})^2 + P_1(t) \cdot (\overline{g_1} - \overline{g})^2$$

Thevariance in the segments is obtained by the sum of both:

$$\sigma_{in}^2(t) = P_0(t) \cdot \sigma_0^2(t) + P_1(t) \cdot \sigma_1^2(t)$$

The threshold value t is chosen in a way that the quotient Q(t) is maximum. Q(t) is, therefore, the measure that we look for. Ths way, we choose the threshold value that optimizes both segments in terms of variance.

III.) Elimination of noise in the image. The noise can be considered as a function f(x,y), added or mixed with an image i(x,y) in a way that the result can be seen as a g(x,y) function , this is:

$$g(x, y) = f(x, y) + i(x, y)$$

A hypothesis is made that in each coordinated pair (x,y), noise is a function without correlation and has a mean value of 0. The supposition is created that, in being able to infer that the noise

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is a function whose equation and behavior can be found, it is derived that its possible, not only to eliminate it, but to introduce it. The npoise is those points, small objects (stains) that appear randomly across the image; these stains have vary in size, density, and shape.

IV.) Obtaining invariable moments (Hu's Moments). The moments are the scalar quantities used to characterize a function and to capture its meaningful characteristics. They have been widely used for hundreds of years in statistics to describe the way a function of density and probability, and in mechanics to measure the distribution of mass of an object. From a mathematical point of view, moments are "projections" of a function on a polygonal base (similarly, Fourier's Transformation is a projection of a harmonic functions).

The general moment of an image $M_{pq}^{(f)}$ represented by $f(x, y)$, where p and q are non negative integers and r = p + q, called the order of the moment, is defined as:

$$M_{pq}^{(f)} = \iint_D p_{pq}(x, y) f(x, y)\, dx\, dy,$$

The most common option is a standard exponential base $p_{kj}(x, y) = x^k y^j$ which leads us to geometric moments.

$$m_{pq} = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} x^p y^q f(x, y)\, dx\, dy.$$

Geometric moments of lower order have an intuitive meaning. –m00 is the mass of the image (for binary regions it's the area of the object). Those of second order describe the distribution of the mass of the image with the coordinated axes

- Each image will undergo the operations to determine its geometric moments, which are obtained in the following manner:
- Substitute image's values in the next formula:

$$m_{pq} = \sum_x \sum_y x^p y^q f(x, y)$$

Fig. 3. Formula to calculate the geometric moments in a set where: The x value is the x component on the pixel's coordinate, the y value is the y component on pixel's coordinate, the f(x, y) function gives the color on (x, y) coordinate, the color could be only black or white, the p and q indexes will be indicated on other function.

- The function to get the unchanging moments to translation it's going to be applied to each image on the next way:
- The image's values are going to be replaced on the next formula:

$$\mu_{pq} = \sum_x \sum_y (x - \bar{x})^p (y - \bar{y})^q$$

Fig. 4. Geometric formula to get the unchanging moments to translation, where the x value is the x component in black pixel's coordinate, the y value is the y component in black pixel's coordinate, the value of: $\bar{x}, \bar{y}$ represents the figure centroid, the p, q indexes will be indicated following .

Provided that:

$$\bar{x} = \frac{m_{10}}{m_{00}}, \bar{y} = \frac{m_{01}}{m_{00}}$$

Fig. 5. Formula to calculate the centroid, in components X and y of a figure, using geometric moments.

The operation will be applied to each image to get the unchanging moments and scale changes, witch are obtained in the next way:

The image's values are replaced in the next formula:

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^{\gamma}}, \gamma = \frac{p+q}{2} + 1, p + q = 2,3,...$$

Fig. 6. Formula to calculate the unchanging geometric moments to translation and scale changes , that uses the miu (μ) indexes, where p and q values are the used indexes to determinate the Hu moments.

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$$\phi_1 = \eta_{20} + \eta_{02}$$
$$\phi_2 = (\eta_{20} - \eta_{02})^2 + 4\eta_{11}$$
$$\phi_3 = (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} - \eta_{03})^2$$
$$\phi_4 = (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2$$
$$\phi_5 = (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] +$$
$$(3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2]$$
$$\phi_6 = (\eta_{20} - \eta_{02})[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] + 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} +$$
$$\phi_7 = (3\eta_{21} - \eta_{30})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] +$$
$$(3\eta_{12} - \eta_{30})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2]$$

Table2. The seven Hu's moments.
The formulas on table 2 indicates the Hu's moment wish to find, that moments has the advantage to be unchanging in rotation, translation and scale, making to flexible image analysis.

5) *K-NN algorithm to pattern recognition.* The k-nn method (K nearest neighbors Fix y Hodges, 1951) is a supervised classification method (Learning, estimation based in a set of training and prototypes) it's used to estimate the density's function F(x / Cj) on the x predictors for each Cj class.
This is the non-parametric classification method that estimates the probability density function's value or the possibility that one x element belongs to Cj class from given information by the prototypes set. On the learning process no supposition is allowed about the predictor variables distribution.

In the pattern recognition, the k-nn algorithm is used to object (elements) classification methods based on training by close examples in element's space. K-nn is a kind of "Lazy Learning" where the function approximates only in local way and ell the computing is deferred to classification.

The training examples are vectors in a characteristically multidimensional space, every example is described in terms of p attributes, considering q classes for the classification. The attribute values of I example (where $1 \leq i \leq n$) are represented by the p-dimensional vector.

$$x_i = (x_{1i}, x_{2i}, ..., x_{pi}) \in X$$

The space is divided on regions localizations and labels of training examples. One point in the space is assigned to the C class if this is the most frequent in the k closest training examples. Generally it's used the Euclidean distance.

$$d(x_i, x_j) = \sqrt{\sum_{r=1}^{p} (x_{ir} - x_{jr})^2}$$

The algorithm's training phase consists of storing characteristic vectors and the class's labels in the training examples. In the phase of classification, the example's evaluation (witch we don't know the class) is represented by a vector in the characteristic space. The distance between the stored vectors and the new vector is calculated, and the k closest examples are selected. The new example is classified with the most repeating class in the selected vectors.

This method supposes that closest neighbors give to us the best classification and this is done using all the attributes; the problem with that supposition it's the possibility that have many irrelevant attributes. Another possibility consist in determinate or tune the weights with known training examples. Finally before of assign weights it's recommendable to identify and eliminate the irrelevant attributes.

In synthesis, the k-nn method is summarized in two algorithms:

Training algorithm
For every example < x,f(x) >, where $x \in X$, add the example to the structure representing the learning examples.

Classification algorithm

Given a xq object, that must be classified, let be x1, x2, …, xk the k closest neighbors to xq in the learning examples, return:

$$\hat{f}(x) \leftarrow argmax_{v \in V} \sum_{i=1}^{k} \delta(v, f(x_i))$$

Where:
δ(a,b) = 1 if a = b, and 0 in other case.

The $\hat{f}(x_q)$ returned value by the algorithm as estimator of $f(x_q)$ is just the most common f value in the k neighbors closest to xq. If we choose k=1; then the closest neighbor to xi determines his value.

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The election of k

The best k election depends fundamentally on data; generally a big k value reduces the noise effect in classification, but creates limits between similar classes. A good k value can be selected by use optimization. The special case witch class is marked to be the closest class to the training example (when k=1) is called **Nearest Neighbor Algorithm.**

The algorithm's exactitude can be severally degraded by the noise presence or irrelevant characteristics, or if the characteristics scales are inconsistent with the considered important. Many researches and efforts were done in the selection and growth of characteristic to improve the classifications. Particularly one approximation in the evolving algorithm use to optimize the scalability characteristics. Another approximation consists in the scaling of the characteristics by the mutual information of the training data with the training classes.

Getting of angles and measures of interest

1) *Color filter.* In this step we are going to filtering the markers color. This is possible by an algorithm that runs over the entire pixel image, pixel by pixel verifying if the RGB values accomplish the indicated conditions. (Example 40<R<200, 0<G<40, 0<B<40).
2) *Transformation to grayscale.* Already described.
3) *Otsu's Threshold Application.* Already described.
4) *Extraction of points of interest.* To this point, the image has to be binarized and the marker filters attached. With the AForge.NET library and the BlobCounter class, the points are extracted, getting as result rectangles on the image.
5) *Angle and points of interest calculate.* Once we have the rectangles, we get the rectangles' center that means the (x, y) identification coordinate. From this we get the line's pending with two known points:

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

Once we got all the line's pending we proceed to calculate the interest angles by the formula to calculate the angle between two lines with known pending:

$$\tan \beta_1 = \frac{m_1 - m_2}{1 + m_1 m_2}$$

Finally in the mach evaluation module the obtained results are processed and compared with the normal march patterns.

3. RESULTS

It's achieved the developing of a system capable of identification, from images of a patient walking, in witch march cycle's phase is, to posterior that march phase, from the explained algorithms in this document, can compare with a normal march pattern and deliver a report that will help the doctors in the patient's treatment. Bringing as consequence to help to improve the life's quality of cerebral paralysis patients, helping the doctor in the diagnosis based on expert's opinion. With this work we achieve the march analysis taking in count the main articulations involved in it. The transparency level for the user makes it easy to implement.
A new technique for the physical movement evaluation in persons has achieved. This technique has the possibility to be adapted and used not only for the march comparing in a cerebral paralysis patient, but else to be used for the sports or other.

4. Conclusions

In this work it has developed a system that allows the analysis and comparing of the march in a paralysis cerebral patient and a normal pattern. For it they have studied and implemented different algorithms of analysis and treatment of images that are acquired under special conditions of the environment.
For the doctor it will be simpler to diagnose the patient already that will be able to see it of way simultaneous from 3 planes (Sagital, frontal and transverse), having a vision that completes of the same one.
The fact of being a topic related to the Medicine, I imply documenting us in a wide way in topics of anatomy, physiology, kinesiología, biomecánica and physical rehabilitation, since all these branches of medicine these related to the human march, in addition of that they helped us

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to have a more wide vision of alterations that the human anatomy and the movement suffers.

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