CLUSTERING ANALYSIS OF PARAPARETICS GAIT PATTERNS

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Summary

The article explains and justifies the hypothesis that different groups of paraparetics gait patterns with the characteristic biomechanical properties exist. The clustering procedure on the set of 90 patterns has been realized. The number of groups has been determined statistically, with criterion based on calculation of mutual information among measured gait parameters.
Results obtained with proposed method simplify and rationalize the problems of gait evaluation procedures, gait functionality or compensatory mechanisms studies, and bring order in the actual clinical classification of gait pathologies.

Introduction

We would be very quick to spot if the pattern of gait was unusual, but we could not say how, exactly. Gait is analized not only for diagnostic purposes but also to assess whether a patient has a reduced ability to walk and whwther a course of treatment has produced a real restoration of function. We think that compexity of the walking drives us to two conclusions. In the first place, we cannot study the gait analytically by eye and, secondly, words and numbers would be a very cumbersome way of expressing of observations if we could. A written report would be lengthly, unintelligible and simply gather dust /1/. It is well known, the objective techniques are only to be found at the moment in research laboratories, but if there is this gap between what the eye can see and what the objective techniques can see.
At present, numerous of the objective techniques are being used in gait analysis, diagnosis, synthesis and evaluation /2,4/. The studies are mostly based on the biomechanical and electroneurological measurement and records. This sort of records are obviously very rich in

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information content but are very poor in presentation. There are reasons why exists the gap between biomechanical and medical approach to the gait study.
The main goal of our investigations is to overcome this gap objectively. This artical propose the clustering technique for solving the problem mentioned above.
Up-to-date publications present that only a few studies of gait based on methods of the artificial intelligence and pattern recognition have been carried out. There are known works by Bekey at 1977 /5/ and by Donath 1978 /6/. The training algorithm has been supervised. On the contrary, we used them supervised learning algorithm for pathological gait patterns classification.

Methodology

Over the last three decades, numerous methods were developed in an attempt to isolate and guantify the gait parameters, both normal and pathological. To this end, walkways have been developed with the instrumentation necessary for measuring the variables of gait /2/. Little sicess has been achieved, however, in the reduction of data which has been generated, to a clinically relevant form /6/. Mentioned facts are the motivation for this study.
The simple gait measurement system, developed by Kralj and Bajd /10/ has been used for determination of 16 basic gait parameters (step time, stride time, stance phase, stride length, push-Off velocity, velocity minimum, minimum velocity occurrence and step lenght, for both legs. Parameters have been estimated from the foot switch timing data measuring, from the centre of gravity /C.G/ velocity recording, and C.G- sagital dispacement recording.

A set of paraparetics gait has been collected comparising 25 subjects. Each patient has been measured more than three times at least two sessions. According to this, the clustering procedure on the set of 90 patterns has been realized. The clustering procedure has based on well known and successful algorithm α /7/. This algorithm has been originally suplemented with modified criterion based on the average mutual information content between gait parameters and parameters of the classification of patterns. The heuristic aproaches have been proposed for determination of the number of classes into the set of the measured data /9,13/.

Results

Figure 1 shows the histogram of the average mutual information content of parameters depending on the number of typical gait classes. The histogram demonstrates that the optimal (maximum mutual information content is detected by K=5) number of classes of paraparetics gait patterns was five (K=5).

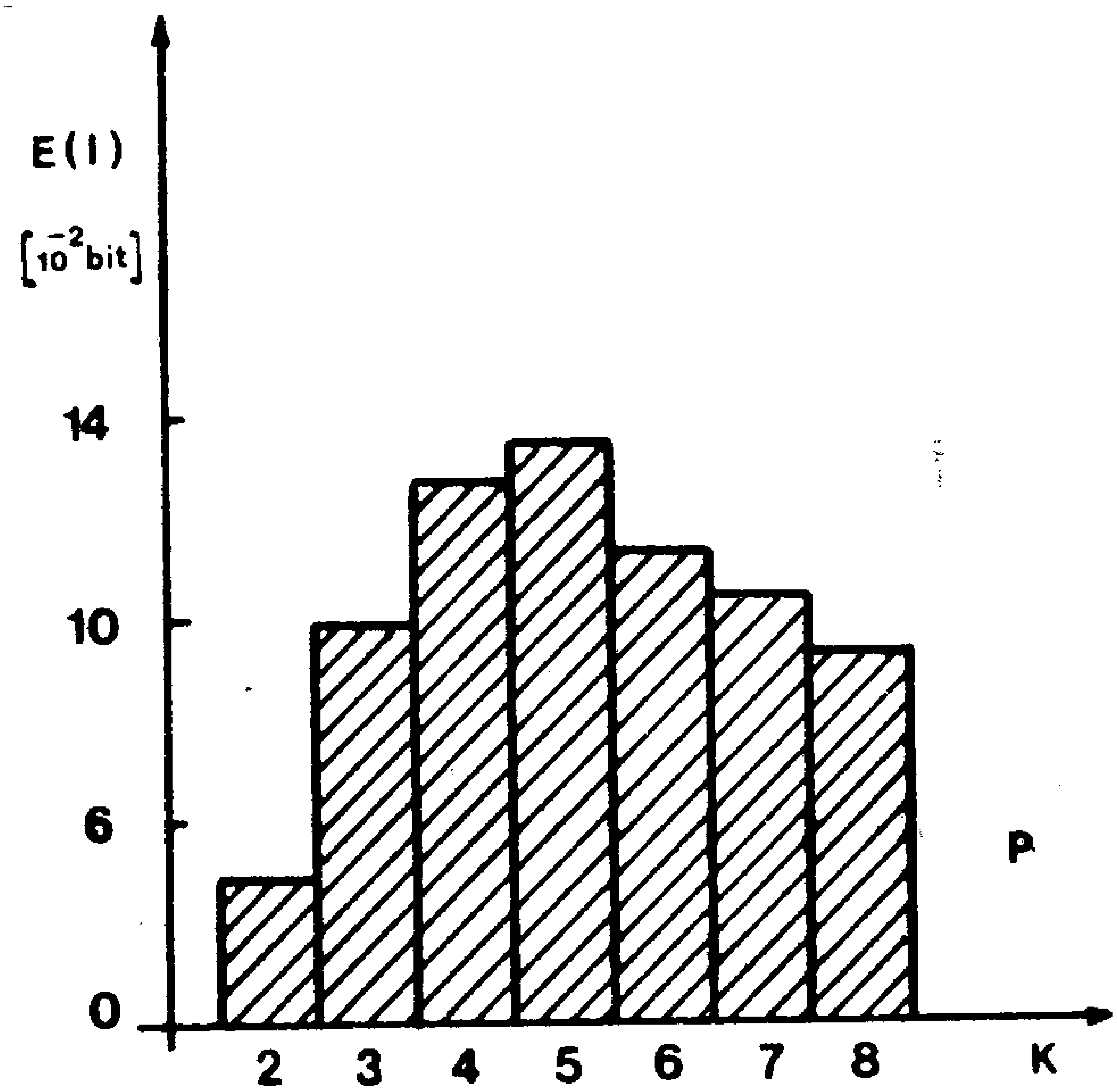

Fig.1 Histogram of the average mutual information content E(I) of parameters depending on K where K means the number of typical gait classes, K=1,2,...8

In Figure 2 we can see that differences among variabilities of parameters are not significant statistically. Diagram demonstrates that the paraparetics gait patterns are obtained in stationary condition, so we measured stacionary gait. This is the proff, that the classification is based primarlly on different biomechanical deficits of patients. The linear momentum changes of the centre of the gravity is expressed with equation (1). This is one of the evaluation criterion corresponding to the dynamic gait properties in the sagital plane.

$$(\Delta G/\Delta T)K = \frac{1}{M_K}\sum_{i=1}^{M_K} \frac{m_i^K \cdot (V_o - V_m)_i^K}{T_i^K} \quad \text{(Newtons)} \qquad (1)$$

where are: M_K - number of patterns recognized into the class K, m_i - mass of i-th subject in kg, $(V_o - V_m)_i^K$ are diferences between push. Off velocity and velocity minimum in ms^{-1} and T_i^K - are time periods at up to push-off velocity to velocity minimum occurence. $i=1,2,...M_K$ and $K=1,2,...5$.

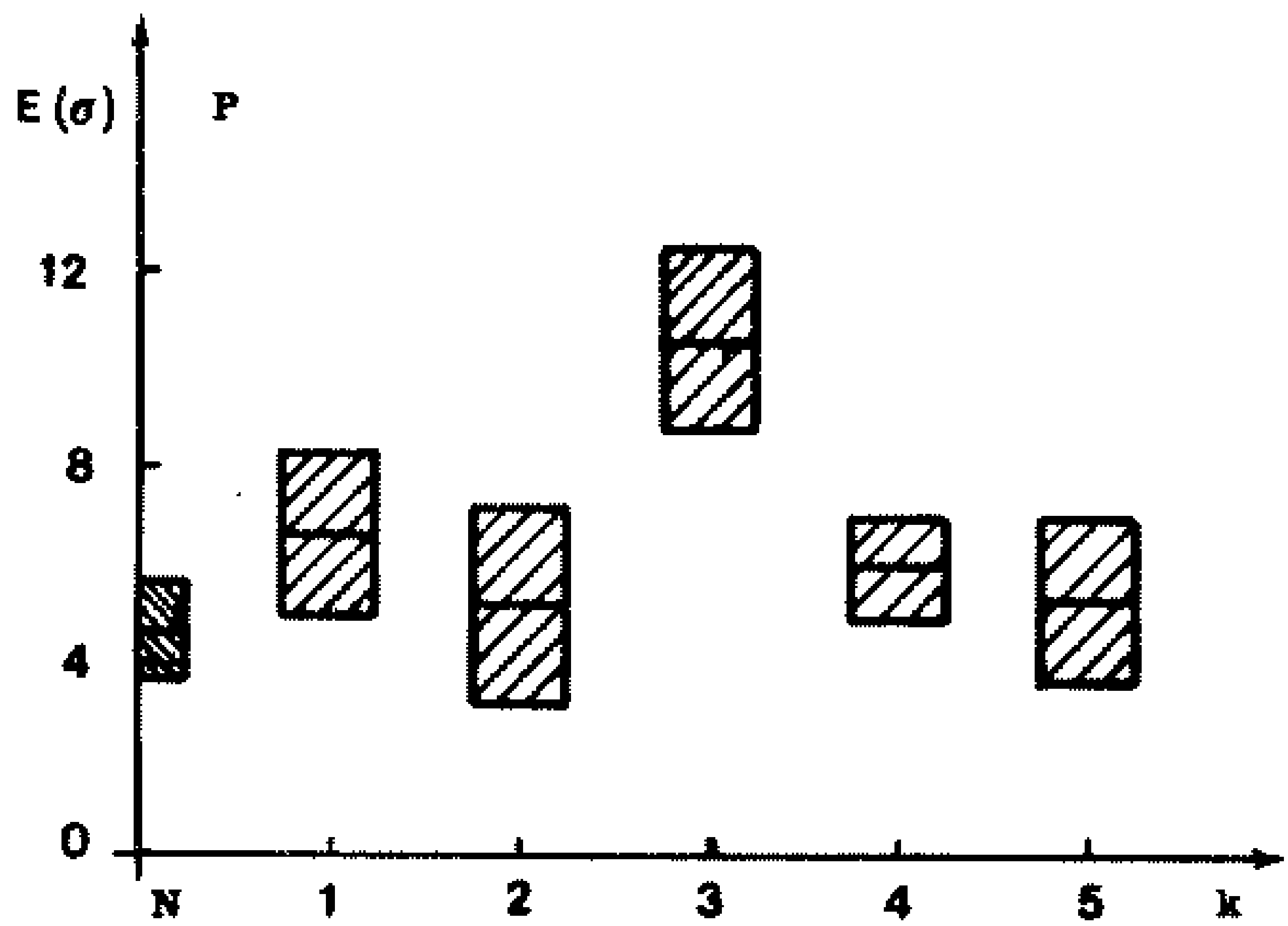

Fig. 2. Histogram of the average variabilities of gait parameters for each class of patterns K.

The results of proposed analysis are presented in Figure 3. Darc squares present right steps and bright the left one. The largeness of squares present the ± standard deviations of linear momentum changes for each class separately (K=1,2,...5). Squere denoted with N prevents the linear momentum changes of centre of gravity for normal subject in average.

The similarity function between normal gait patterns X and pathological patterns Y_K has beam used for determination the kinematic evaluation criteria. X and Y^K are vectors estimated from the measurements and determined by clustering procedure, where K is the number of class.

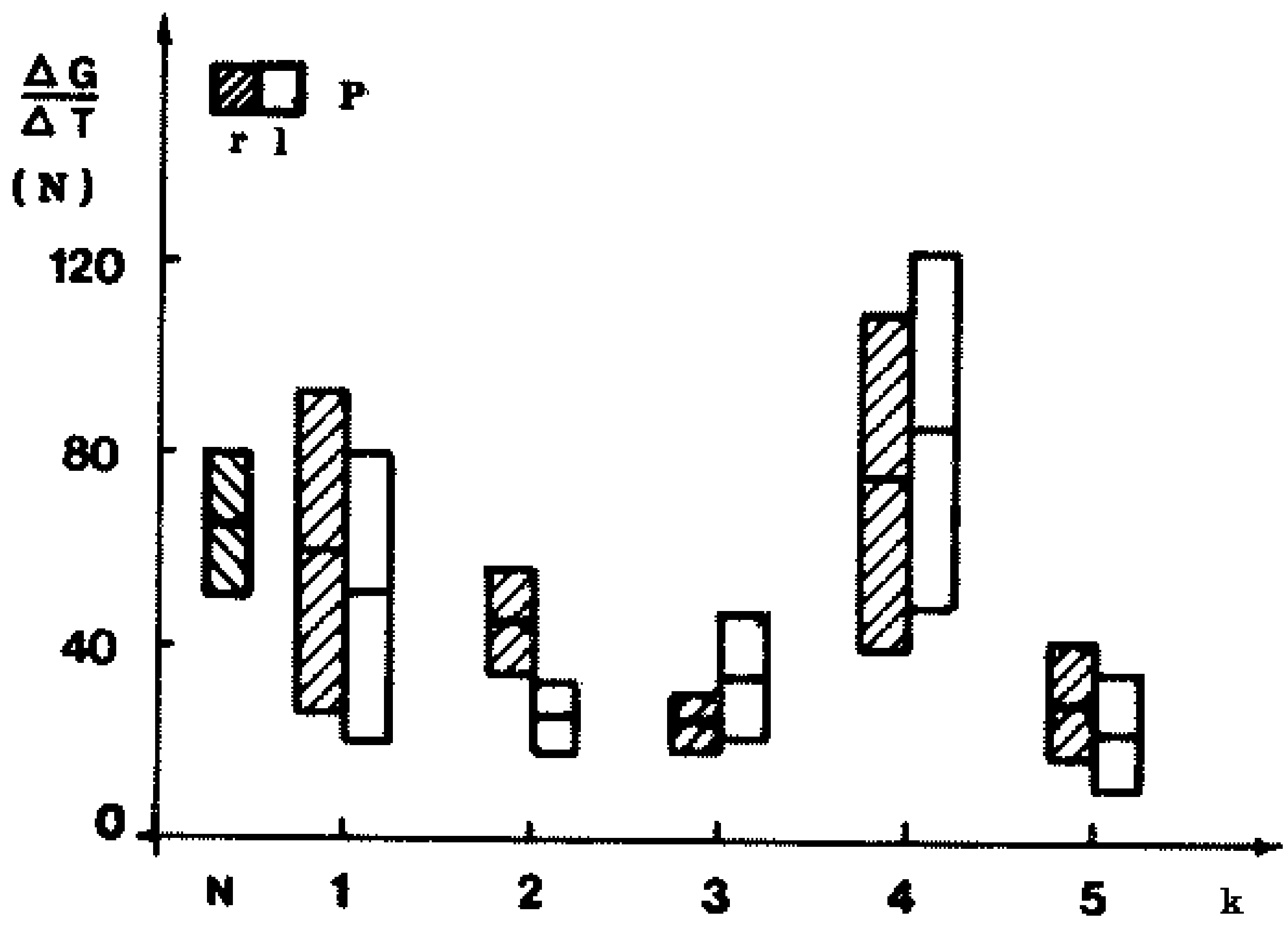

Fig.3 Histogram of linear momentum changes in dependance of gait pattern classes K = 1,2,...5

The criterion was based on equation 2.

$$E(dn)_K = ((X - Y_K)^T \cdot (X - Y_K))^{1/2} \qquad (2)$$

The results of calculation are presented in Fig.4.

If the column in the histogram is lower, the gait patterns are more similar with the normal patterns in average. We can see that the third class is the "worst", and the fourth is the best one. The fourth class has abnormal high linear momentum (Fig.3). Objectively, we can conclude, that the fourth class of patients presents functional compensating mechanism, erased on the increased dynamic of movement of the centre of gravity of patients body.

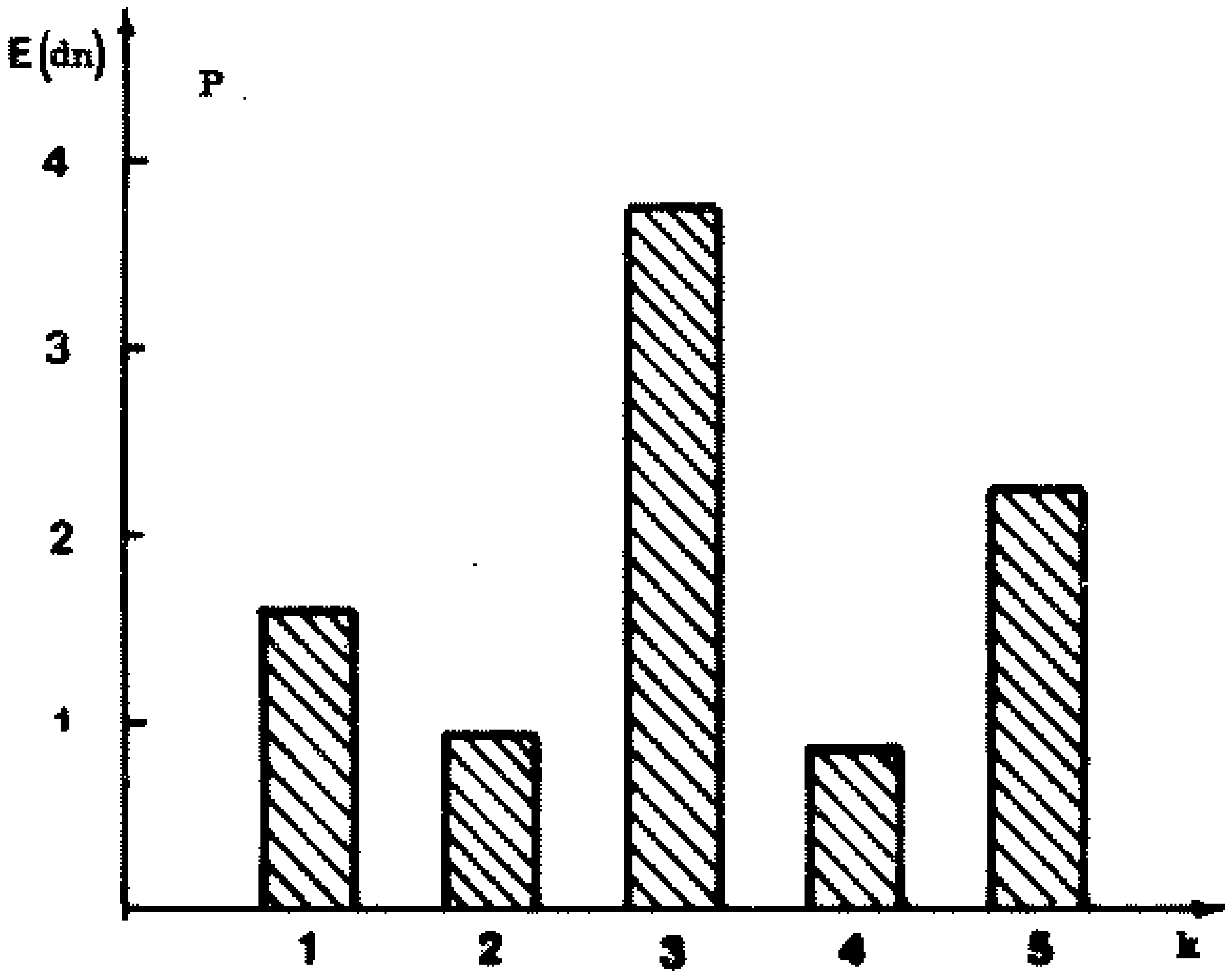

Fig. 4. The similarity of paraparetics gait patterns classes on the normal gait pattern

Conclusions

Analysis and evaluation of gait with pattern recognition methods gave us new knowledge about compensatory mechanisms. This should be taken intoaccount for prescription of FES and later for gait school control.

We found out that velocity parameters include a lot of information about gait properties. There is no good kinematic gait measurement without carefully determined velocity parameters. The dynamic criteria which we introduced with the simplified model based on the measured parameters we also of the utmost importance.

We made and evaluated a simple and low cost measurement system for on line gait evaluation. The system is continually used in our kinesiological laboratory. We determined the natural and typical paraparetics, gait classes and introduced the new criteria for gait evaluation based on pattern recognition. For measuring of movements in lateral plane an additional measurement equipment is necessary, while mathematical methodology remains unchanged.

We believe that the pattern recognition technology introduced to the gait evaluation field will permit a new insight into the problems and let us proceed a step forward in the gait evaluation field which has not been progressing in a systematic manner for a number of years.

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