

## Development of correlative investigation technique (CIT) of human performances in specific conditions of postural malfunctions

Mihaela Ioana Baritz<sup>1</sup> and Diana Laura Cotoros<sup>2</sup>

<sup>1</sup> University Transilvania from Brasov, Precision Mechanics and Mechatronic Department

<sup>2</sup> University Transilvania from Brasov, Mechanics Department

**Abstract.** In this paper we present some theoretical and practical considerations concerning the development procedures of some correlative investigation techniques (CIT) applied to human performances analysis expressed in specific evolution conditions of some postural malfunctions. These integrated correlative techniques may define and control by feed-back reactions the behavior of some bio-systems or even of some automated and robotized systems.

**Keywords:** component; correlation; investigation; human behavior; posture.

### 1. Introduction

The correlative techniques used for structural and modular analyzes of human bio-behavior represent one of the most efficient and important methods used to highlight and assess the environmental influences and of the external stimuli upon the postural skills of the subjects. From the point of view of the standardized definition of the correlation operation "Correlation is a measure of the relation between two or more variables". The measurement scales used should be at least **interval scales**, but other correlation coefficients are available to handle other types of data. Correlation coefficients can range from -1.00 to +1.00. The value of -1.00 represents a perfect **negative correlation** while a value of +1.00 represents a perfect **positive correlation**. A value of 0.00 represents a lack of correlation. The most familiar measure of dependence between two quantities is the Pearson product-moment correlation coefficient, or "Pearson's correlation." It is obtained by dividing the covariance of the two variables by the product of their standard deviations. Karl Pearson developed the coefficient from a similar but slightly different idea by Francis Galton. [1]

The population correlation coefficient  $\rho_{X,Y}$  between two random variables  $X$  and  $Y$  with expected values  $\mu_X$  and  $\mu_Y$  and standard deviations  $\sigma_X$  and  $\sigma_Y$  is defined as:

$$\rho_{x,y} = \text{corr}(X, Y) = \frac{\text{cov}(X, Y)}{\sigma_x \sigma_y} = \frac{E[(X - \mu_x)(Y - \mu_y)]}{\sigma_x \sigma_y}$$

where  $E$  is the expected value operator,  $\text{cov}$  means covariance, and,  $\text{corr}$  a widely used alternative notation for Pearson's correlation.

The Pearson correlation is defined only if both of the standard deviations are finite and both of them are nonzero. It is a corollary of the Cauchy-Schwarz inequality that the correlation cannot exceed 1 in absolute value. The correlation coefficient is symmetric:  $\text{corr}(X, Y) = \text{corr}(Y, X)$ . The Pearson correlation is +1 in the case of a perfect positive (increasing) linear relationship (correlation), -1 in the case of a perfect decreasing (negative) linear relationship (**anticorrelation**), and some value between -1 and 1 in all other cases, indicating the degree of linear dependence between the variables. As it approaches zero there is less of a relationship (closer to uncorrelated). The closer the coefficient is to either -1 or 1, the stronger the correlation between the variables.[1] If the variables are independent, Pearson's correlation coefficient is 0, but the converse is not true because the correlation coefficient detects only linear dependencies between two

variables. For example, suppose the random variable  $X$  is symmetrically distributed about zero, and  $Y = X^2$ . Then  $Y$  is completely determined by  $X$ , so that  $X$  and  $Y$  are perfectly dependent, but their correlation is zero; they are uncorrelated. However, in the special case when  $X$  and  $Y$  are jointly normal, uncorrelatedness is equivalent to independence. If we have a series of  $n$  measurements of  $X$  and  $Y$  written as  $x_i$  and  $y_i$  where  $i = 1, 2, \dots, n$ , then the *sample correlation coefficient* can be used to estimate the population Pearson correlation  $r$  between  $X$  and  $Y$ . The sample correlation coefficient is written like in following relation [1]:

$$r_{x,y} = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{(n-1)s_x s_y} = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2 \sum_{i=1}^n (y_i - \bar{y})^2}}$$

where  $\bar{x}$  and  $\bar{y}$  are the sample means of  $X$  and  $Y$ , and  $s_x$  and  $s_y$  are the sample standard deviations of  $X$  and  $Y$ .

Another fundamental issue related to the correlative techniques is represented by the causality of some events that are analyzed with respect to the correlation procedures. We found that the correlative technique does not involve causality in the way that this procedure cannot be used to intervene in the causal relations between the variables. This is why this aspect should not signify the fact that correlations cannot point out the existence of possible causal relations. For example in the biomechanics analyzes there is an obvious correlative relation between age and height (ideal) but less obvious and analyzed is the correlation between the psychical state and health because we cannot clearly establish which one of them is the determinant factor, the causal one and the affected one.

Another extremely important aspect is represented by the linearity characteristic of the correlation. The Pearson correlation coefficient indicates the strength of a linear relationship between two variables, but its value generally does not completely characterize their relationship. In particular, if the conditional expectation of  $Y$  given  $X$ , denoted  $E(Y|X)$ , is not linear in  $X$ , the correlation coefficient will not fully determine the form of  $E(Y|X)$ . [1] From different examples of the literature we may remark that the correlation coefficient as a statistic function cannot replace the data individual examination and their interpretation, taking into account the dependency factors. Thus, it is enough that one value of the individual examination string is outside the other data distribution in order to produce a strong correlation process, even if the relations between the variables are not linear. Because the examinations category in case of the experiments regarding postural malfunctions analysis are strongly influenced by different environmental conditions, by different categories of subjects or by other imposed or known factors it is many times more practical to use the property of *correlation coefficient concordance* (CCC) defined as the agreement between two variables, e.g., to evaluate reproducibility or for inter-rater reliability. Reproducibility of some experiments especially in the biomechanical analysis that work with subjects' samples having different characteristics, represents one of the basic scientific methods and refers to the ability of an experiment to be accurately reproduced in another location or using different similar equipments allowing similar results. Thus, the reliability of a statistical data processing system concerning the subjects' evaluation may determine an intra-class correlation that is used in its turn as a statistic descriptor for the quantity measurements of the variables (results of determinations upon subjects), organized in groups.

The *intraclass correlation* is commonly used to quantify the degree to which individuals with a fixed degree of relatedness resemble each other in terms of a quantitative trait. Another prominent application is the assessment of consistency or reproducibility of quantitative measurements made by different observers measuring the same quantity. In a range of researches we established that the inter-class correlations may be regarded as sequences of some analysis of variance (ANOVA). ANOVA is a collection of statistical models associated to some procedures or correlative techniques by help of which we aim at the variance of a variable divided in its turn in components attributed to different variation sources.

ANOVA is an extremely practical method in the analysis upon subjects' samples because it can process more groups of data, establishing the processes correlations or concordances or variables. ANOVA, accepting linear models as responses of the processes, allows also that these responses include a range of properties such as: *cases independence* (a property that facilitates a lot statistic analysis; *normality* (statistic

distribution is considered normal); *homogeneity* (data variant within the same group is the same). In statistic studies upon samples categories we may use a range of ANOVA types. When someone designs experiments, especially the ones in the category of random spread data (e.g. values of the forces on Oz developed during gait), the protocol describing the spreading mechanism may include a specification of the data processing method (e.g. threshold value for starting recorded force determined by the initial weight of each subject).

The most used protocols of the ANOVA types are:

- a. *One-way ANOVA* is used to test for differences among two or more independent groups. Typically, however, the one-way ANOVA is used to test for differences among at least three groups, since the two-group case can be covered by a **t-test** (**t-test** is any statistical hypothesis test in which the test statistic follows a Student's *t* distribution, if the null hypothesis is supported). When there are only two means to compare, the **t-test** and the **ANOVA F-test** (**F-test** is any statistical test in which the test statistic has an F-distribution under the null hypothesis) are equivalent and the relation between ANOVA and *t* is given by  $F = t^2$ . [1]
- b. *Factorial ANOVA* is used when the experimenter wants to study the interaction effects among the treatments.
- c. *Repeated measures ANOVA* is used when the same subjects are used for each treatment.
- d. Multivariate analysis of variance (MANOVA) is used when there is more than one response variable.

## 2. Experimental setup

In experimental analysis performed for developing integrated correlative techniques used for the study of human factor behavior, we considered a recording system of the forces developed on the ground along a gait cycle, force plate type. This equipment allows the recording of forces and moments on three directions (Ox, Oy, Oz) at the foot-ground contact both in the static stability determination process and in the dynamic stability.

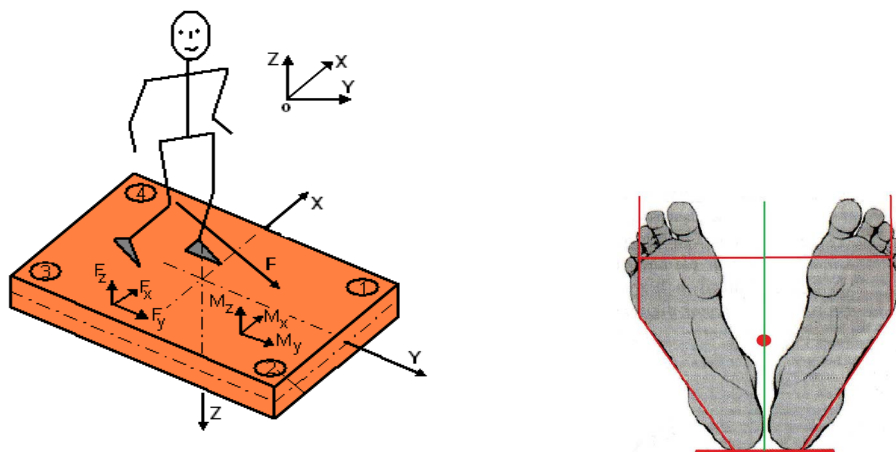


Fig.1. Force plate Kistler type

The used method was based upon the ANOVA model for the determined sample of 21 subjects (12 women and 9 men). Data acquisitions were accomplished in the same environmental conditions and following the same trail of the recording procedures. For a better analysis of the correlative analysis methods we selected three recording variants having as a variable parameter the displacement direction of the tips with respect to the displacement axis. In this respect we established three situations:

- The positioning direction of the tips is parallel to the displacement direction;
- The positioning direction of tips is convergent to the displacement direction (tips towards inside);
- The positioning direction of tips is divergent form the displacement direction (tips towards outside).

The signals coming from the force plate are recorded and then processed using *Bioware* software so that the numerical results of forces, moments and displacement amplitudes of the centre of mass projection inside the stability area, become now initial data of the ANOVA type analysis samples.

### 3. Results and Conclusions

The procedure consisted at first of the recording action performed upon subjects in unitary conditions and second, of the correlation action of the same type of measurements. Thus we recorded the forces along Oz measured by the 4 sensors and we graphically represented them (example of a female subject, height 1,65 m, weight 83 kg) and this type of values were then analyzed by an ANOVA correlation type.

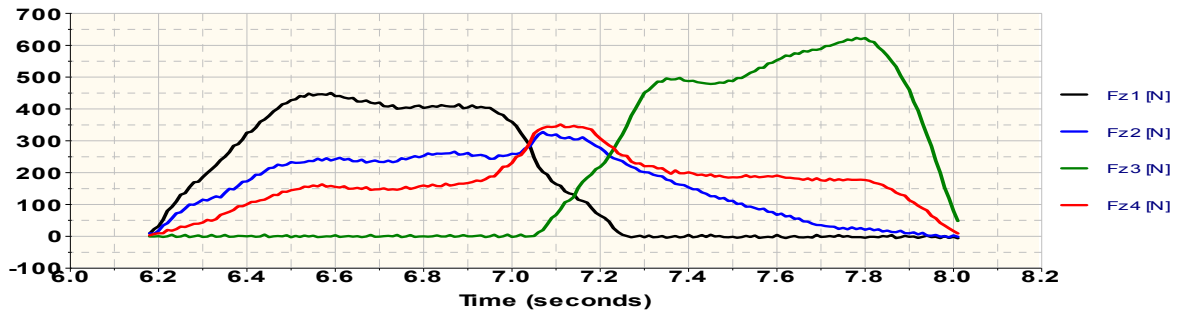


Fig.2. Forces on Oz recorded by the 4 sensors in normal gait

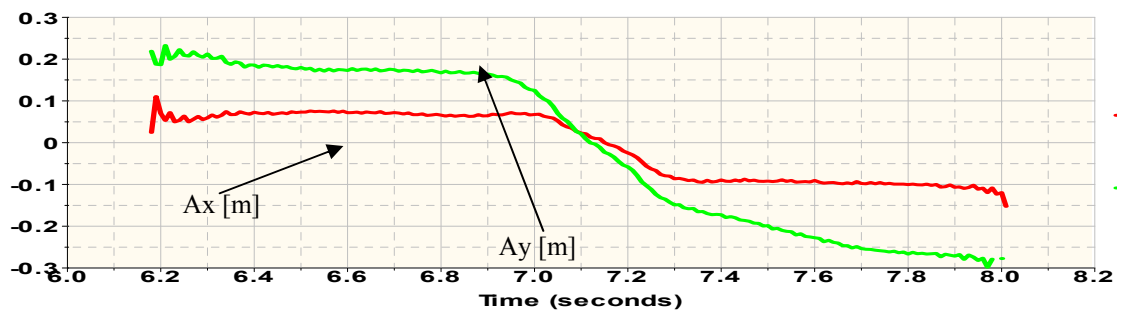


Fig.3. Displacement amplitudes variation, Ax and Ay of the centre of mass projection inside the stability area during a normal gait cycle

Then the measurements included the chosen variants for displacement and in these cases the forces measured along Oz by the 4 sensors are presented in fig.4, fig.5, fig.6 and fig.7.

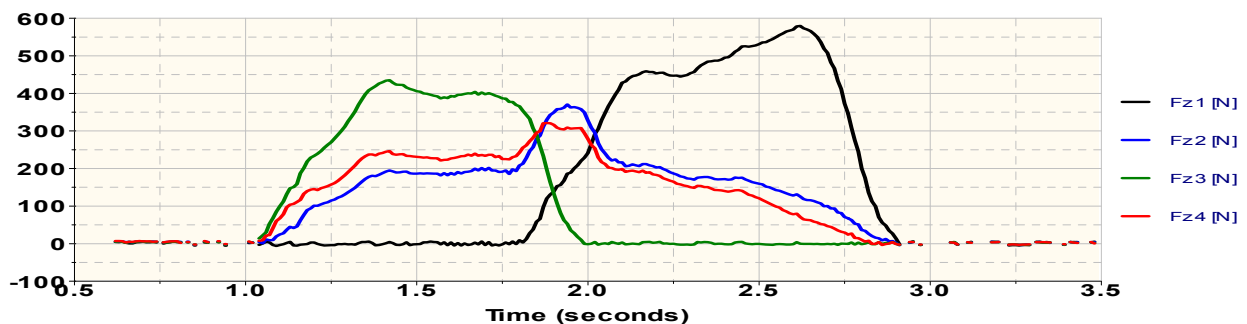


Fig.4. Forces along Oz recorded by the 4 sensors in divergent gait

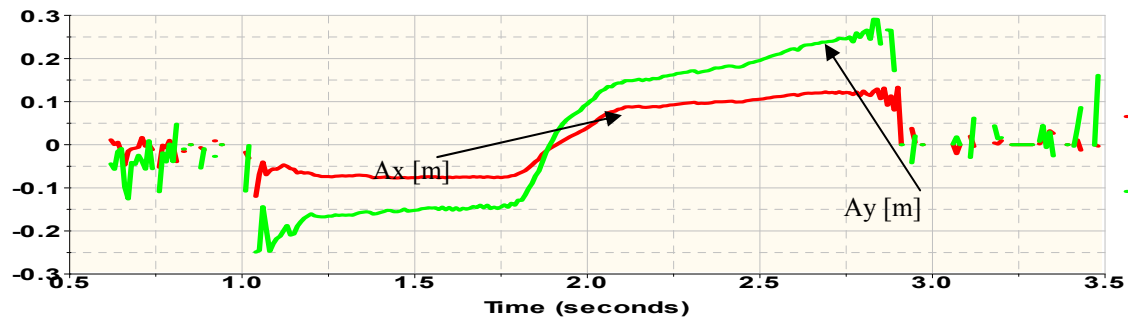


Fig.5. Displacement amplitudes variation  $A_x$  and  $A_y$  of the centre of mass projection inside the stability area along a divergent gait cycle (strongly towards outside)

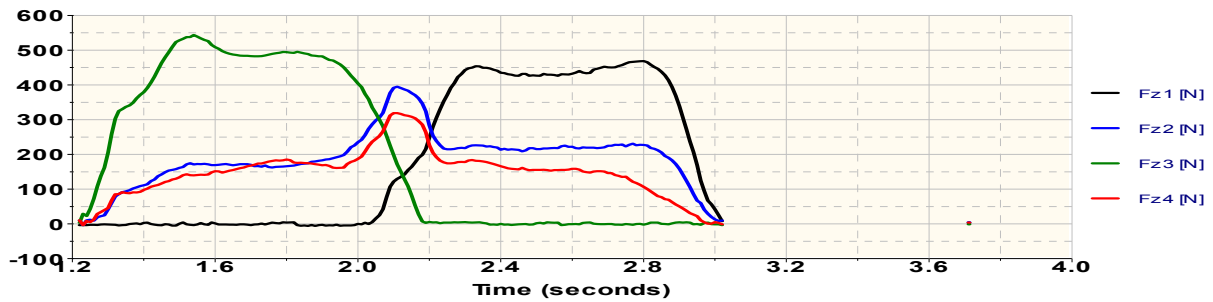


Fig.6. Forces on  $Oz$  recorded by the 4 sensors in convergent gait

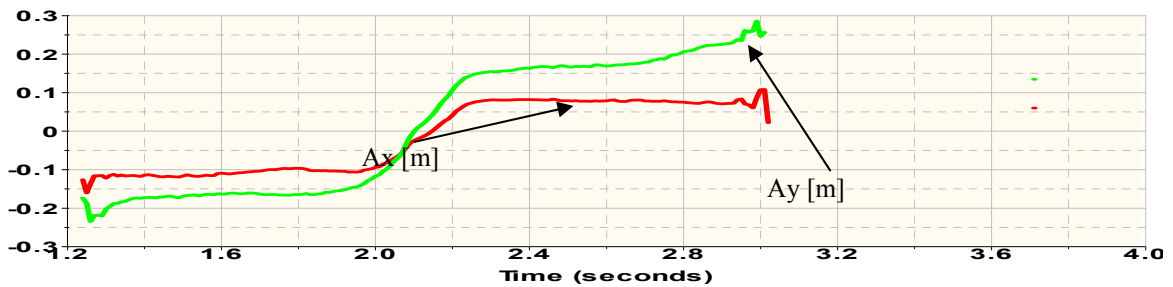


Fig.7. Displacement amplitudes variation  $A_x$  and  $A_y$  of the centre of mass projection inside the stability area along a convergent gait cycle (strongly towards inside)

The recorded results for the subjects' samples were introduced in the correlation procedure after performing some preliminary operations, to obtain results by ANOVA for the following values: total  $F_z$ ,  $F_{z1}$ ,  $F_{z2}$ ,  $F_{z3}$ ,  $F_{z4}$ ,  $A_x$  and  $A_y$ .

In the next tables we presented the results for the same subject analyzed for different types of walking and where the total  $F_z$  variable is calculated by ANOVA procedure.

Tabel 1

Values	Samples			
	1	2	3	Total
N	150	150	150	450
$\sum X$	12255	12044	12242	36541
Mean	81.7	80.2933	81.6133	81.2022
$\sum X^2$	1005955	978430	1005820	2990205

Variance	31.6879	76.3563	45.0307	51.2129
Std.Dev.	5.6292	8.7382	6.7105	7.1563
Std.Err.	0.4596	0.7135	0.5479	0.3374

Tabel 2

Source	SS	df	MS	F	P
<b>Treatment</b> [between groups]	186.431	2	93.215	6.44	0.00182
<b>Error</b>	4310.90	298	14.466		
<b>Ss/BI</b>	18497.264	149			
<b>Total</b>	22994.597	449			

Ss/BI = Subjects or Blocks depending on the design, applicable only to correlated-samples ANOVA

We used the three walking types (1=normal walk, 2=outside walk, 3=inside walk), we determined the mean, variance, deviation and standard error.

The number of samples in each test was the same, namely 150 measurement points of the total force on Oz, along the entire duration of a gait cycle.

As we may notice the values are the following HSD[.05]=1.03; HSD[.01]=1.29 and M1 vs M2 is P<.01, then M1 vs M3 is non-significant, respectively M2 vs M3 is P<.01.

HSD = the absolute [unsigned] difference between any two sample means required for significance at the designated level.

HSD[.05] for the .05 level; HSD[.01] for the .01 level.

ANOVA for Fz (gait normal, ext. and int.)

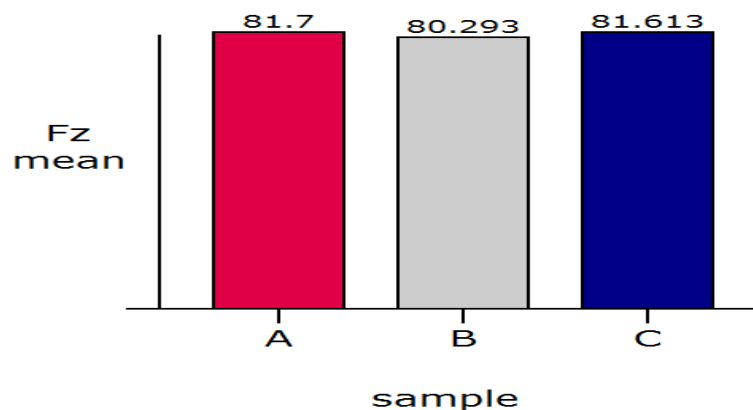


Fig. 8. Graphical representation of the correlations between the values of the forces measured in the three situations for the same subject (A=normal walk, B=outside walk, C=inside walk)

The total results are processed and the final conclusion is that the values of the forces developed on Oz, by the 4 sensors are in correlative process to the feet position along the duration of a gait cycle, determining the development of different reactive responses.

A practical application of these reactive responses is represented by the possibility of dimensioning the rehabilitation and recovery procedures of some dynamic postural malfunctions.

#### 4. Acknowledgements

These researches are part of the Grant PNII-IDEI 722 with CNCSIS Romania and we've developed the investigations in *Advanced Mechatronic Researches* Department from University Transilvania Brasov.

## 5. References

- [1] [http://en.wikipedia.org/wiki/Correlation\\_and\\_dependence](http://en.wikipedia.org/wiki/Correlation_and_dependence) - accessed march 2011;
- [2] Pronost N., Definition et realisation d'outils de modelisation et calcul de mouvement pour des humanoïdes virtuels, these PhD., 2006, l'Universite de Rennes 1, France;
- [3] Motulsky H., Statistics guide for PRISM-Statistical analyses for laboratory and clinical researches, graph pad, 2003;
- [4] Juras G. Et al., Evaluation of the Limits of Stability (LOS) Balance Test, *Journal of Human Kinetics* volume 19 2008, 39-52;
- [5] Graham C. et al., The influence of spatial errors in species occurrence data used in distribution models" *Journal of Applied Ecology* 2008,**45**, 239–247;
- [6] Michael Tiffany, A Survey of Event Correlation Techniques and Related Topics , 2002;
- [7] Kejonen P., Body movement during postural stabilization-Measurements with a motion analysis system, Department of Physical Medicine and Rehabilitation, University of Oulu, 2002;
- [8] Prpic T. Et al., The Influence of Test Repetition on Bipodal Visually Controlled Static and Dynamic Balance, *Coll. Antropol.* **34** , 2010, Suppl. 1: 135–139;
- [9] <http://faculty.vassar.edu/lowry/VassarStats.html> - accessed march 2011.