RESEARCH METHODOLOGY IN ZAGREB KINESIOLOGY CIRCLE

Franjo Prot

Faculty of Kinesiology, University of Zagreb, Croatia

Abstract

In this paper development of research methodology in Zagreb kinesiolgiy circle is presented. It is stated that form 1960's Zagreb kinesiology circle kinesiology was developing as contemporary science of human movement. It is based on the principles and methodological developments appropriate to the research problems imposed and resolved. As a central and dominant figure of methodological developments is recognized prof. Konstantin Momirović PhD. (1932-2004). "He made kinesiology into a research field" as noticed by prof. Ingram Olkin (2008). Multivariate data analysis and statistics had been a core of his research methodology considerations. His role of active contributor to both the theoretical and applied developments is stressed. Development of ideas on research methodology and multivariate data analysis, in kinesiology as a science, it is presented trough several recognized phases. In the first, initialization phase, methodological topics had been treated as an act of assimilation of ideas and techniques from close related and more developed social scientific disciplines (i.e. psychology etc.). In the second phase "Zagreb Methodological and Multivariate Data Analysis Circle" at the University of Zagreb (Institute of Kinesiology at the Faculty of Physical Education and at the University Computing Centre - SRCE) had been established, where completely new ideas emerged. In the third phase he influenced and organized various productive groups of researchers, so the circle became a school which influenced other social sciences too. Within these three periods some sub phases and several areas of interest are relatively easy recognized. Evolution of some of the most influential ideas, algorithmic solutions and program implementations are demonstrated. Finally, his contributions and influences are divided in the same way as they are grouped and incorporated into the SPSS macro language coded library of seven hundred and sixty macro programs (Prot, F., A. Hosek, K. Bosnar, V. Luzar-Stiffler, V. Hljuz Dobric, Z. Bekić, M. Gredelj (2008)). This short overview is the core of a more elaborate presentation scheduled for Key note speech to the Research Methodology section of 5th . International conference on Kinesiology at Zagreb 2008.

Key words: *Research methods in kinesiology, Zagreb kinesiology circle, Konstantin Momirović, Multivariate data analysis, Robust Methods, Measurement Theory, SS Statistical System*

Introduction

From its early beginnings in 1960 Zagreb kinesiology circle have been developing around the contemporary science of human movement based on the methodological developments appropriate to the research problems imposed and resolved.

Based on his biography and extensive bibliography professor Kosnstantin Momirović (1932-2004) has been recognized as a central and dominant figure of methodological developments in kinesiology as it have been started to develop in Zagreb academic and sport communitiy, "He made kinesiology into a research field" as noticed by prof. Ingram Olkin (2008) a professor form Stanford University. He had been an active contributor to both the theoretical and applied developments.

From the very beginning Momirović (1968) presented the importance of scientific foundation of applied fields in area of physical culture ("Utjecaj naučne zasnovanosti fizičke kulture na njenu društvenu afirmaciju" i.e. "The Influence of the scientific foundations of physical culture on its social affirmation"). Kinesiology along with mathematics, biology, physiology, psychology and sociology have been recognized as one of fundamental sciences in are of phenomenology of physical culture.

Phenomenological complexity urges multivariate approach in research. So, Multivariate data analysis had been a core of research methodology considerations. From the point of view of development of ideas on research methodology and multivariate data analysis, in kinesiology as a science, it is possible to recognize several phases. In the first, initialization phase, he worked on methodological topics as an individual assimilating and developing contemporary ideas. In the second phase, he influenced and became the originator and principal figure in the so called "Zagreb Methodological and Multivariate Data Analysis Circle" at the University of Zagreb (Institute of Kinesiology at the Faculty of Physical Education and at the University Computing Centre - SRCE) where completely new ideas emerged. In the third phase he influenced and organized various productive groups of researchers, so the circle became a school influenced other social sciences too. Within these three periods some sub phases are recognized, as well. In each of these phases and sub phases several areas of interest are relatively easy to recognize. Evolution of some of the most influential ideas, algorithmic solutions and program implementations are demonstrated. Finally, his contributions and influences are divided in the same way as they are grouped and incorporated into the SPSS macro language coded library of seven hundred and sixty macro programs (Prot, F., A. Hosek, K. Bosnar, V. Luzar-Stiffler, V. Hljuz Dobric, Z. Bekic, M. Gredelj (2008)). This short overview is the core of a more elaborate presentation scheduled for Key note speech to the Research Methodology section of 5th . International conference on Kinesiology at Zagreb 2008.

It seems that the easiest way to introduce Konstantin Momirović (1932-2004) to the interested reader is through his personal biography, as follows: *Born in 1932 in Tetovo (Macedonia). Graduated from elementary and high school in Belgrade. He received his BS degree in psychology from the Faculty of Philosophy of the University of Zagreb in 1955, and his PhD in psychometrics from the University of Zagreb in 1963. From 1955 to 1959 he was employed as clinical psychologist and head of the Laboratory for Applied Psychology at the Military Hospital in Zagreb. From 1960 to 1966 he acted as head of the Laboratory for Experimental Design and Statistics at the Institute for Developmental Problems of Children and Youths in Zagreb. He was Assistant at the Faculty of Physical Education from 1960 to 1963; Assistant Professor from 1963 to 1966; Associate Professor from 1966 to 1971; Full Professor of Psychology and Quantitative methods from 1971 to 1990 at the same faculty. In the period from 1971 to 1990 he acted as Head of Research and Development Division and as General Manager (1979-1983) of the University Computing Centre - SRCE at the University of Zagreb. From 1991 to 1997 he was Full Professor of Statistics at the Faculty of philosophy of the University of Belgrade, and from 1991 on he acted as Scientific Consultant and Chief Project Manager at the Institute of Criminological and Sociological Research.*

His visiting positions include: Professor of Statistics and Computer Programming in graduate and postgraduate studies at the Faculty of Mathematics and Mechanics of Moscow University, Faculty of Applied Mathematics and Cybernetics of Moscow University, Faculty of Medicine of the University of Zagreb, Faculty of Defectology of the University of Zagreb, Faculty of Philosophy of the University of Zagreb, Faculty of Economics of the University of Sarajevo, and faculties of Physical Education at Universities of Belgrade, Ljubljana and Novi Sad. He mentored MA, PhD, MD and BS degree students at Universities of Zagreb, Belgrade, Ljubljana, Sarajevo and Novi Sad.

The main fields of scientific interest of Dr. Momirović are statistics, mathematical psychology and criminology. He published 38 books and around 500 scientific and professional papers in scientific journals or monographs of statistics, computer science, psychology, sociology, biological anthropology and kinesiology. Dr Momirović is a member of International Statistical Institute, Psychometric Society, European Anthropological Association, International Association of Statistical Computing, Statistical society of Serbia and Anthropological Association of Yugoslavia.

Konstantin Momirović (1932-2004), alias Stojan Hadžigalić, among his close friends and colleagues known as “Kosta” has been an exceptionally active and productive contributor to the theoretical and applied developments of multivariate data analysis since the very beginning of his research career in early 1960’s, as can be seen from his rich bibliography (Prot, F., A. Hosek, K. Bosnar, V. Luzar-Stiffler, V. Hljuz Dobric, Z. Bekić, M. Gredelj (2008)) and autobiographic and biographic reports prepared for promotions and rewards, such as in Momirović (1976), Kališnik, Goričar and Ulaga (1979), Bujas, Petz, and Mraković (1983), Momirović (1989, 2004), or in published or unpublished In Memoriams (see e.g., Fajgelj (2004), Macura (2004), Prot (2004), and Vlahović and Kovačević (2005)).

It is possible to recognize several phases of development of Momirović’s ideas on research methods and multivariate data analysis and statistics in kinesiology: In the first, initialization phase, from 1957 to 1970 he worked on methodological topics as an individual assimilating and developing contemporary ideas. His contribution to the design of Statistical System (SS) prepared the ground floor for the organized and systematic work; In the second phase, from 1971 to 1990, he became an originator and principal figure of the so called “Zagreb Methodological and Multivariate Data Analysis Circle” at University of Zagreb (Institute of Kinesiology at the Faculty of Physical Education and the University Computing Centre - SRCE) where completely new ideas emerged; In the third phase, from 1991 to 2004, he further extended and developed his research ideas in his new working environment. In each of these phases and sub-phases several areas of interests are rather easily recognized.

One of the first available real evidence of his familiarity with multivariate data analysis is his state-of-the-art (for the time being) and extensive overview of methods for factor analysis, which makes a substantial part of his doctor degree thesis titled “Factor structure of neurotic symptoms” (Momirović,1963, chapters 3 and 4, pages 71 – 195). He concluded his thesis with reaffirmations of modified multi group method (Thurstone, Holtzinger, Burt, Horst, Harman, Momirović) as a mean for structural hypotheses testing in the field of data analysis. Additionally, he fully developed and applied hierarchical algorithm for the modified multigroup method up to the third level of extracted factors (Momirović,1963, chapter 5, pages: 196 – 317).

The most obvious demonstration of his familiarity with interrelated problems and their treatment (by applying various multivariate data analysis methods) can be found in his investigation of validity of psychological tests and measurements (Momirović K., 1966; in Krković, A., K. Momirović, and B. Petz, 1966). Early on, his research interest focused on interrelated application of various methods for factor analysis (including multi group method) as means for estimating construct validity. On the basis of degenerated, simple summation method, algorithms for pseudocanonical correlations analysis, regression analysis and discriminant analyses were developed as methods for establishing pragmatic i.e. predictive and classification validities of measurement instruments. In this phase he examined equivalences between canonical discriminant and Q method of factor analysis, the problem of usefulness of factor scores in canonical discriminant analysis. He presented modified iterative Q method of factor analysis (and the accompanying algorithm) for determination of psychological types to psychologist and to a group of researchers in the emerging field of Kinesiology. Stimulated with the problem of penology treatment evaluation he proposed to evaluate structural changes using the canonical correlation (alienation) model and hierarchical factor solutions where he investigated relations between manifest variables and multidimensional higher-order factor spaces (Momirović, K.; 1969, 1969, 1969). These were research problems which prepared him to open a new stage of systematic research in the field of multivariate methods for transformation and condensation in data analysis (Momirović, K. (1972), "Methods for transformation and condensation of kinesiological data"). On page 303 it was stated that all of the methods and algorithms are going to be coded in FORTRAN IV for IBM series 1130 and 370/165 electronic computers. It had been realized that a collections of statistical and data analysis subroutines (once developed) should be interrelated into a general statistical language.

The research program incorporated in "Methods for transformation and condensation of kinesiological data" resulted in very interesting contributions which considerably influenced algorithm and application development. Full assimilation of Guttman and Harris ideas results with new treatment of problem of initial metrics of variables. The problem of latent structures of manifest variables have been analyzed considering the specific properties of initial metric of variables, and a series of new criteria for determining the number of retained factors were proposed (e.g., PB ("Plum Brandy") criterion (Momirović, K. and J. Štalec, 1971)). The concept of images of variables in Guttman sense has been extended to generalized image transformations of one set of variables to the another set of variables and vice verse (Momirović, K., J. Štalec, E. Zakrajšek, 1973). This theoretical contribution anticipated developments in data analysis which will extend and relax already established dominance of classical canonical correlation model as a general and fundamental model for variety of methods for data analysis. Guttman's Image theory and its extensions were also applied to the problems of homogeneity, representativeness and reliability of psychometric measurements. Above mentioned and other related developments were incorporated in real research environment in various areas of applications. Influential (classical) books on multivariate analysis (Anderson, 1958; Harman; 1960, 1967; Horst, 1965; Rao, 1958, 1973; Cattell, 1966, Morrison, 1967; Cooley and Lohnes 1971; Mulaik, 1972; Bock, 1975) have further stimulated deeper insight and research in the area.

On this occasion only a few of Momirovic's achievements and contributions will be covered in detail, especially some of those which were accomplished while he had been an active researcher at the Institute of Kinesiology and University Computing Centre - SRCE of the University of Zagreb and which were further developed later on during his extraordinary successful career.

Some Influential Methodological Contributions

Methodological research and achievements after 1971 could be divided into the following three areas of data analysis:

1. Kinesiometrics (development of new theoretical and applied measurement models in the field of measurement theory)
2. Multivariate data analysis and statistics (new models, methods and algorithms for data analysis)
3. Informatics (a field of computer science related to the development of new software for information systems, data analysis and management)

Proposed names and labels of these sub-fields were introduced and became part of the standard terminology used in the curricula at graduate and postgraduate studies.

Kinesiometrics
(development of new theoretical and applied measurement models in the field of measurement theory)

It was K. Momirović, who introduced the term "kinesiometry" in his lecture notes for the course entitled "Short course in kinesiometry"("Kratki kurs iz kineziometrije"; 88 pp) conducted at postgraduate study of Kinesiology during 1971/72, as illustrated in Figure 1. The term had been included in the Anić and Goldstein dictionary (Anić and Goldstein, 1999) at page 675, as illustrated in Figure 2.

PRIMIJENJENA KINEZIOLOGIJA
Kratki kurs iz kineziometrije

To je naučna disciplina koja se bavi problemima mjerenja u kinezio-
logiji. Budući da smo već prije utvrdili da u ozbiljnoj znanosti mo-
žemo utvrditi znanstvene zakonitosti samo na temelju kvantitativnih
veličina ili veličina koje se mogu kvantificirati, očito je da je
proces mjerenja fundamentalan proces za svaku znanost uopće pa tako
i za našu znanost. Problemi mjerenja povezani su sa rješavanjem ne-
kih teoretskih i nekih praktičnih problema. Osnovni teorijski proble-
mi koji se moraju riješiti u vezi sa bilo kojom procedurom mjerenja
su prije svega svrha zbog koje se mjerenje vrši. Mjerenja sama po
sebi nikada ne predstavljaju nešto što ima kao takvo znanstvenu vri-
jednost. Mjerenja su samo operacije koje omogućavaju znanstvena is-

Figure 1. A part of the first page of student notes for the course on Kinesiometrics ("kineziometrija") at postgraduate study of Kinesiology, years 1971/72 at the College of Physical Education (today Faculty of Kinesiology).

-kineza, -kinezija, -kinetički kao drugi dio riječi označava ono što se odnosi na kretanje, gibanje; pokretan, kretni [*diskinezija*] ◇ *grč.* kínēsis: kretanje; kinētikós: koji pokreće

kinezi-, kinezio- *v.* kine-

kinezàlgija *ž med.* bol koja se javlja pri kretanju, osobito kod mišićnih napora ◇ KINEZI- + -ALGIJA

kineziològija *ž* **1.** znanost o gibanju, kretanju; istražuje zakonitosti posebno uvjetovanih tjelesnih vježbi **2.** studij na sveučilištima, ob. studij tjelesne kulture ◇ KINEZIO- + -LOGIJA

kineziomètrija *ž term.* znanstvena disciplina koja se bavi problemima mjerenja u kineziologiji ◇ KINEZIO- + -METRIJA

Figure 2. The term kinesiometrics "kineziometrija" was introduced to Anić-Goldstein's dictionary at page 675 (Anić and Goldstein, 1999).

In measurement theory alternative approaches to classical test theory are constantly being examined. These alternative approaches were applied (by K. Momirović and his associates) in construction and reconstruction of composite measurement instruments (composite tests and questionnaires) (see e.g., Momirović (1966, 1969, 1972, 1974); Zakrajšek, Momirović and Dobrić (1976, 1977); Momirović and Gredelj (1980); Bosnar (1980); Momirović, Gredelj and Dobrić (1981); Momirović, Pavičić and Hošek (1984); Momirović (1988)). A new general model for the estimation of error of measurement, along with the measures of reliability and representativeness were proposed (Momirović, 1974; Momirović and Dobrić, 1976; Zakrajšek, Momirović and Dobrić, 1977; Momirović, Dobrić and Gredelj, 1978; Momirović and Gredelj, 1980; Momirović, Pavičić and Hošek, 1984). Additionally, upper and lower bound of reliability (under the new general model) were derived (Momirović, 1974, 1975; Momirović, Pavičić and Hošek, 1984). That enabled objective definition and estimation of homogeneity independently from the reliability itself. (Momirović, 1974, 1977).

We'll try to illustrate some of these achievements, most of which were developed while K. Momirović has been affiliated to SRCE (Zagreb). Methods for determination of internal metric properties of measurement instruments had been continually in focus of his attention. Based on full assimilation of ideas of Guttman (1954) and Harris (1963) he generalized the classical test theory, the generalization being that the errors of measurement are permitted to exhibit correlation and nonconstant variability.

Momirović was constantly improving algorithms and implementations of programs for the analysis of metric characteristics of composite measurement instruments ("RTT" programs) from the initial SS program (MAPANAL) through the upgraded versions RTT7 (Statistical System, Momirović, 1980), RTT8 (GENSTAT version, Momirović and Prot 1986), RTT9/10 (SPSS macro version; Momirović and Knežević, 1996), to the most complex and general RTT12G SPSS implementation.

To briefly illustrate some of Momirović's original contributions to the analysis of metric properties of composite measurement instruments, let us define a set E as a set of n entities randomly selected from a homogeneous population P, and let T be a composite measurement instrument composed from m items measured on a continuous or on an ordinal scale. Let Z be a matrix of standardized (normalized, if necessary) results which describe set E over the set T. Then $\mathbf{R} = \mathbf{Z}^t\mathbf{Z}\mathbf{n}^{-1}$ and $\mathbf{U}^2 = (\text{diag } \mathbf{R}^{-1})^{-1}$ denote the correlation matrix and a diagonal matrix of estimated error variances, respectively. Error variables could be defined as antiimage variables (i.e., $\mathbf{E} = \mathbf{Z}\mathbf{R}^{-1}\mathbf{U}^2$), and true parts as image variables (i.e., $\mathbf{T} = \mathbf{Z}(\mathbf{I} - \mathbf{R}^{-1}\mathbf{U}^2)$. The respective covariance matrices are:

$\mathbf{A} = \mathbf{E}^t\mathbf{E}\mathbf{n}^{-1} = \mathbf{U}^2\mathbf{R}^{-1}\mathbf{U}^2$, and

$\mathbf{G} = \mathbf{T}'\mathbf{T}\mathbf{n}^{-1} = \mathbf{R} + \mathbf{U}^2\mathbf{R}^{-1}\mathbf{U}^2 - 2\mathbf{U}^2$.

Then the covariances between observed (**Z**) and true variables (**T**) are $\mathbf{P} = \mathbf{Z}'\mathbf{T}\mathbf{n}^{-1} = \mathbf{R} - \mathbf{U}^2$, and covariances between observed (**Z**) and error variables (**E**) are $\mathbf{Z}^t\mathbf{E}\mathbf{n}^{-1} = \mathbf{U}^2$.

Let $\mathbf{M} = \mathbf{Z}\mathbf{U}^{-1}$, represent the observed variables transformed to the "universal" metric, where $\mathbf{H} = \mathbf{M}^t\mathbf{M}\mathbf{n}^{-1} = \mathbf{U}^{-1}\mathbf{R}\mathbf{U}^{-1}$ (see e.g. Harris (1962)).

Let **x**, **y**, **v** and **w** denote normalized eigenvectors and let λ^2, δ^2, ω^2 and η^2 denote eigenvalues of the matrices **R**, **G**, **P** and **H**, respectively.

Some examples of Momirović's original contributions regarding representativeness, reliability, homogeneity and convergence of metric indicators are presented in the following paragraphs.

REPRESENTATIVENESS: measures how the measurements are representative regardless of whether the synthetic composite measure is computed or not. Most of these measures were originally proposed by Kaiser (1970). Konstantin Momirovic proposed the following extensions: A measure of absolute lower bound of representativeness ψ_4 (Momirović, Dobrić and Gredelj, 1978), which is identical to absolute lower bound of reliability under Guttman's measurement model $\psi_4 = 1 - \eta^{-4}$, and ψ_5 (a measure proposed by Momirović and Hošek) defined as

$\psi_5 = ((\mathbf{s}^t(\mathbf{G} * \mathbf{G})\mathbf{s})(\mathbf{s}^t(\mathbf{R} * \mathbf{R})\mathbf{s})^{-1})^{1/2}$,

where s is a summation vector of order m.

RELIABILITY: Under the classical test theory model (CTT), the reliability of a test can be defined as $\alpha = \psi^2\sigma^{-2}$, where ψ^2 and σ^2 are variances of true part, and of total score, respectively. Alternatively $\beta = 1 - \varepsilon^2\sigma^{-2}$, where ε^2 is the error variance. Within CTT α and β are equivalent, but under the alternative model (by Momirović referred to as "Guttman's model") α and β are not equivalent. Momirović and his fellow researchers developed a series of reliability measures. Some of them, included in SPSS macro program "RTT12G" are as follows: absolute lower bound for component of standardized items $\mu_1 = 1 - \lambda^{-2}$; Lower bound of β as $\beta_1 = (1 - \lambda^{-2})^2$ and upper bound as $\beta_2 = 1 - \lambda^{-4}$ proposed by Momirović, Dobrić and Gredelj (1977); and $\beta_6 = 1 - (\mathbf{x}^t\mathbf{U}^2\mathbf{x})\,\lambda^{-2}$ proposed by Momirović (1996); Measures of reliability of component of items transformed into image form $\tau = \delta^2\lambda^{-2}$ Momirović (1975) and $\gamma = \omega^2\lambda^{-2}$ Momirović and Knežević (1991). In addition to Guttman-Nicewander $\lambda_6 = 1 - \eta^{-2}$, new measures of reliability (of the first component of standardized items rescaled to Harris universal metric) were proposed, i.e. lower bound $\rho_1 = (1 - \eta^{-2})^2$ as a completely new approach by Momirović and Dobrić (1977), and upper bound $\rho_2 = 1 - \eta^{-4}$ by Zakrajšek, Momirović and Dobrić (1977). A new extension of image transformation, mirror image analysis, and its application to reliability theory was examined by Momirović, Gredelj and Dobrić (1981).

HOMOGENEITY: In addition to the standard measure (i.e., the average of correlations among items), a series of new alternative measures were devised. Measure of relative variance of first principal component of items transformed into image form $h_2 = \delta^2\xi^{-2}$ Momirović (1977); measure defined by the number of components with non negative reliability was proposed by Momirović and Gredelj (1980) as $h_4 = 1 - (k - 1)(m - 1)^{-1}$ where $k = \text{num } (\lambda^2_p > 1)$ and λ^2_p, $p = 1,...,m$ are eigenvalues of matrix **R**; measure $h_5 = 1 - (\theta^2 - \lambda^2)(m - \lambda^2)^{-1}$ (Knežević and Momirović (1995)), where θ^2 is the sum of k eigenvalues of matrix **R**, and another one defined as $h_6 = 1 - (\theta^2 - \lambda^2)(m - 1)^{-1}$; in addition, $h_7 = (\lambda^2 - 1)(\theta^2 - 1)^{-1}$ was proposed by Momirović and Knežević (1995).

CONVERGENCES OF INDICATORS: Momirović proposed one class of convergence measures of indicators which means that proportional conformity of item results to the first principal component. Let

$\mathbf{G} = \mathbf{R} + \mathbf{U}^2\mathbf{R}^{-1}\mathbf{U}^2 - 2\mathbf{U}^2$ and

$\mathbf{V} = (\text{diag}\mathbf{G}^{-1})^{-1/2}$

and let δ_1, δ_2 and δ_m be the first, second and mth eigenvalue of the matrix G. The following measures of convergences were proposed:

$\varphi_1 = 1 - \delta_1^{-1}$; $\varphi_2 = 1 - \delta_2\,\delta_1^{-1}$; $\varphi_3 = \delta_1 m^{-1}$;

$\varphi_4 = 1 - 2^{-1}(\delta_2 / \delta_m)\delta_1^{-1}$, $\varphi_5 = 1 - (\text{trace V})m^{-1}$

and a measure of convergence defined as relative informativity $\varphi = (1 - \mu_1)^{-1}m^{-1}$ where μ_1 is the absolute lower bound of the first principal component of items.

The new stage of development was achieved using neural network methodology. As an example RTT13HNN (Momirović, 2002) is an emulation of Hopfield neural network (Hopfield, 1982) for the estimation of sampling adequacy, reliability and homogeneity of composite measurement instruments. The basic procedure is the estimation of Guttman anti image and image variables (Guttman, 1953) by a simple modification of Hopfield network, and then the calculation of suitable modifications of Kaiser - Rice measure of sampling adequacy of items, denoted here as ψ_4 (Kaiser and Rice, 1974), Guttman sixth lower bound to reliability of result obtained by simple summation of item scores, usually referred to as λ_6 (Guttman, 1945), Momirović lower bound to reliability of result defined by the first principal component, usually referred to as β_6 (Momirović, 1996) and Momirović second measure of homogeneity h_2 (Momirović, 1977). Construction of Hopfield network for the estimation of anti image and image variables and technique of computation of measures ψ_4, λ_6, β_6 and h_2 can be easily understood from the symbolic code of the program itself (Momirović, 2002).

Taking into account the diversity of initial metrics of variables, i.e. nonstandardized and standardized real, and transformed into Guttman's and Harris' space, different criteria for extractions of latent dimensions, different parsimonious transformations, new explorative and confirmative models were recommended for estimation of validities of measurement instruments (Momirović, 1966, 1970, 1973; Bosnar and Prot, 1981; Prot and Momirović, 1984; Momirović, Erjavec and Radaković, 1988; Bosnar, 1989, Prot and Bosnar, 1989).

Multivariate Data Analysis and Statistics
(new models, methods and algorithms for data analysis)

The field of data analysis, and specially the area of multivariate statistical methods, had been a subject of majority of methodological research. At a time, new methods and algorithms were proposed for component analysis (Momirović and Gredelj, 1980; Prot, Viskić-Štalec, Štalec, Bosnar, Momirović and Knap, 1984), taxonomic analysis (Momirović and Zakrajšek, 1973; Momirović, Szirovicza, Gredelj and Dobrić, 1980; Momirović, Hošek, Bosnar and Prot, 1984; Prot, Zenkin, Momirović, Bosnar and Knap, 1984; Prot, Viskić-Štalec, Štalec, Bosnar, Momirović and Knap, 1984; Momirović and Mildner, 1989), multidimensional scaling (Momirović, Bosnar, Štalec and Prot, 1983), canonical correlation (Momirović, Gredelj and Herak, 1980), multivariate regression (Momirović, Szirovicza, Dobrić and Gredelj, 1980) and discriminative analysis (Momirović, Dobrić and Szirovicza, 1979; Momirović, Szirovicza, Dobrić and Gredelj, 1980) analysis of nonnumerical (qualitative) data, which enabled applications of complex procedures in data analysis and hypotheses testing of data with weak metric properties. An algorithm of classical type had been implemented (Zlobec, Varga and Momirović, 1974). More advanced, multivariate approach, based on spectral decomposition of contingency tables was utilized (Bosnar and Pavičić, 1982; Bosnar and Hošek, 1983; Momirović, 1989). New complex integrative algorithms which support interpretation of realistic research data of so called nonquantitative data.

One of the classical problems, the problem of criteria for determination of number of important latent dimensions had been critically examined (Momirović, Kovačević, Ignjatović, Horga, Radovanović, Mejovšek, Štalec and Viskić-Štalec, 1972). Series of new criteria had been proposed and comparatively tested in real standardized metric (Štalec and Momirović, 1971), Guttman's nonstandardized and standardized space (Zakrajšek and Momirović, 1972; Momirović and Štalec, 1973; Momirović, Štalec and Zakrajšek, 1973) and Harris metric as well. Based on these experiences, a new general principle for determination of criterion in all metrics of analyzed variables had been developed (Momirović and Štalec, 1984). Principles of criteria construction for determination of number of important dimensions were generalized to the problem of analyses of relations of sets of variables (Dobrić, Momirović and Gredelj, 1987).

An algorithm for hierarchical component analysis in image space was developed (Prot and Bosnar, 1981; Dobrić and Momirović, 1984). Concurrent and comparative evaluation studies of component and factor analysis methods were provided (Momirović, Viskić-Štalec, Štalec, Mejovšek, Ignjatović, Radovanović, Horga and Kovačević, 1972; Viskić and Štalec, 1982; Viskić-Štalec 1987; Bosnar and Prot, 1994).

Canonical factor analysis model and component model in Harris' space have been studied and completely new algorithm for pseudocanonical component model has been developed (Bosnar, Prot, Momirović, Lužar and Dobrić, 1982). Estimation of factor score values had been studied as well (Radaković and Momirović, 1987). An algorithm for iterative multigroup method of factor analysis had been improved (Gredelj, Štalec and Momirović, 1983). On the basis of these experiences new different procedures which integrate explorative and confirmative approach in determination of latent spaces of sets of manifest variables were developed (Momirović, 1972; Momirović, Gredelj and Štalec, 1977; Szirovicza, Gredelj and Momirović, 1978; Štalec and Momirović, 1982; Bosnar, Prot, Štalec and Momirović, 1984; Cvitaš and Momirović, 1984; Viskić-Štalec, Štalec and Momirović, 1984; Knezović and Momirović, 1986; Momirović, Erjavec and Radaković, 1988).

Methods for identification of structural similarities or differences of matrices of covariances or crosscovariances were developed for the analyses of structural changes (Dobrić, Karaman and Momirović, 1983; Bosnar and Prot, 1984; Momirović, Prot, Dugić, Bosnar, Erjavec, Gredelj, Kern and Dobrić, 1987; Cvitaš and Momirović, 1985, 1987; Prot, Bosnar, Hošek and Momirović, 1984; Prot, Ivančević and Momirović, 1985; Prot and Bosnar, 1987).

Multivariate analysis of time series had been treated under the spectral decomposition of data matrices of individuals-INDIFF (Momirović and Karaman, 1982; Karaman and Momirović, 1984; Prot, Momirović and Bosnar, 1987), and groups-COLDIFF (Momirović and Karaman, 1982; Pavičić, Karaman and Momirović, 1983; Bosnar, Momirović and Prot, 1987).

Significant results were achieved it the field of taxonomic analysis. The model of polar taxons has been treated from the point of view of different metrics of variables (Momirović, 1978; Momirović, Zakrajšek, Hošek and Stojanović, 1979; Momirović, 1981).

Integration of explorative and confirmative approach in determination of taxonomic dimensions enabled new methods for pattern recognition and multicriteria selection were developed, with or without linear constraints imposed (Prot and Bosnar, 1982; Momirović, Dobrić and Karaman, 1984; Prot, 1985, 1989; Momirović, 1989; Momirović and Mildner, 1989).

Canonical discriminative model had been studied from the formal point of view. Regarding the metrics of initial set of variables, a generalized discriminant procedure (Momirović, Gredelj and Herak, 1981), and a general program for multivariate analysis of variance were developed (Pavičić and Momirović, 1982). It had been found that Mahalanobis transformation of variables offers appropriate numeric and interpretative form for canonical discriminative analysis (Bosnar, Momirović and Prot, 1984).

Systematic application of generalized image transformation of sets of variables (Momirović, Štalec and Zakrajšek, 1973) resulted in definition of some of general measures of associations (Momirović and Dugić, 1986; Gredelj and Momirović, 1988). Symmetric and asymmetric measures of association of sets of variables were defined. Under the concept of generalized image transformation with suitable restrictions, it was possible to develop all of the methods for symmetric and asymmetric relations among sets of variables (Prot, Bosnar and Momirović, 1983, 1983; Bosnar, Prot and Momirović, 1985).

BICANAL method of canonical correlation analysis of images of variables, inspired by Tim and Carlson’s (1976) bipartial canonical correlation analysis, has been successfully developed, implemented and applied (Gredelj, Momirović, Dobrić, Herak, Bosnar and Prot, 1982; Hošek, Bosnar, Prot and Momirović, 1984). Bi-partialisation of external sets of variables led to a new algorithms, i.e. bipartial canonical covariance analysis (Momirović, 2001).

Formal properties of relations among sets of variables were examined (Momirović, Štalec, Zakrajšek, 1973; Momirović, Dobrić, 1979; Bosnar, Prot, Momirović, 1985; Bosnar, Prot, 1988).

A class of robust methods for multivariate data analysis were proposed to enable processing of data that do not satisfy assumptions necessary for the application of classical data analysis methods. The advantages of the proposed methods are in their robustness both to outliers and to the artificial associations generated by the few pairs of variables from two different sets. Furthermore, this variables need neither be normally distributed nor their covariance matrices need be regular.

Canonical Covariance Analysis (QCR), Momirović, Dobrić and Karaman (1983). Relations between the canonical and quasicanonical correlation analysis can be found in Momirović, Bosnar and Prot (1984), Momirović and Dobrić, (1985), and Knežević and Momirović (1996). The influences of initial metric of variables on the results of applied algorithms of quasicanonical analysis of covariances were examined: Harris universal (Dobrić, Momirović and Gredelj, 1985), Guttman’s partial image (Momirović, Dobrić and Gredelj, 1985), standardized image (Wolf, Radaković and Momirović, 1988), and between Guttman and Harris metric (Momirović, Dobrić and Gredelj, 1985).

Robust Redundancy Model. Under the generalized image transformation with suitable restrictions it was possible to develop different methods for symmetric and asymmetric methods of relations of sets of variables (Prot, Bosnar and Momirović, 1983, 1983; Bosnar, Prot and Momirović, 1985).

SRA model of regression analysis, Štalec and Momirović (1983). All that relations between SRA and LSR regression could be found in Dobrić, Štalec and Momirović (1984). The influences of different metrics and scaling of variables on the results of quasicanonical regression analysis had been also treated (Momirović, Dugić and Gredelj, 1987; Matečić and Momirović, 1988; Momirović, 1988),

SDA Model of robust discriminant analysis, Štalec and Momirović(1984). Furthermore, the properties of that model had been defined in Harris universal space (Milonja, Dobrić and Momirović, 1989), Hotelling space (Gredelj, Dobrić and Momirović, 1989), and Pearson space (Momirović, 1989).

The interrelations of results of canonical covariance analysis, multivariate redundancy analysis and regression analysis suggest a method of spectral analysis of relations of general images of variables named “nuclear analysis” (Hošek and Momirović 2001).

NUCLEAR ANALYSIS (Hošek and Momirović 2001) Nucleus of two sets of quantitative variables is defined as the cross covariance matrix of the variables mutually transformed to generalized image form (Hošek and Momirović, 2001). The singular values decomposition of nuclear matrix is named nuclear analysis. Because spectral analysis of any cross covariance matrix is actually canonical covariance analysis of two sets of variables, transformed to some selected metrics, it was possible to derive identification structures such as pattern, intercorrelations and structure matrices.

Beside the methods for robust analysis of hypothetical latent dimensions (Štalec and Momirović, 1982; Dobrić. Karaman, Momirović, 1983), and robust analysis of hypothetical taxonomic dimensions (Štalec, Bosnar, Prot, Momirović, 1982), the problem of relations between sets of variables had been successfully treated as well.

In order to clarify the interpretation of obtained results, relationships between robust methods and corresponding classical methods were established and examined. The formal relations between canonical correlation analysis and quasicanonical analysis of covariances were established (Hošek, Bosnar and Prot, 1984; Knežević and Momirović, 1996); quasicanonical analysis of covariances and principal component analysis (Gredelj, Momirović and Dobrić, 1986), least squares regression analysis and robust regression analysis (Dobrić, Štalec and Momirović, 1984). Diagnostic efficacy of robust discriminant analysis had been investigated (Momirović and Dobrić, 1988).

The taxonomic analysis of microsocial structures represented by binary graphs were solved by spectral decomposition of matrix of network of relations (Momirović, Hošek, Bosnar and Prot, 1984) and multidimensional scaling (Petrović and Momirović, 1972).

In Hotteling space (space of left eigenvectors of data matrices) general models were established where classical methods of data analyses could be treated as special cases (Momirović, Gredelj and Herak, 1978; Bosnar, Prot and Momirović, 1985: Momirović and Dobrić, 1988; Gredelj, Dobrić and Momirović, 1989).

Konstantin. Momirović continuously integrated new ideas related to acquisition, analysis and interpretations of results of data analysis procedures. In the field of development and applications of artifical neural networks new algorithms were developed for almost all relevant methods of data analysis. The nonlinear nature of results obtained by these new methods has significantly contributed to further data analysis conteptualisation beyond the classical general linear model based multivariate methods. Interesting results were obtained in taxonomic problems (Momirović, 2003; Popović and Momirović, 2003; Momirović, Hošek, Popović and Boli, 2003; Momirović, 2003; Momirović and Hošek, 2003; Knežević, Momirović, Radovanović and Radović, 2003; Bosnar, Prot, Momirović and Hošek, 2003; Prot, Bosnar, Hošek and Momirović 2003; Popović, and Momirović 2003).

Informatics/Applied Computer Science

(design and development of information systems, designing new software tools for information systems, and multivariate data analysis and management)

The experiences and research problems Momirović has been faced with, and solutions he proposed were related to the multivariate nature of problems, the size of problems and the availability of computer resources (lack or limited access to computer resources) at the time being.

He has been very active in promoting and implementing the ideas of establishment of modern, contemporary, computing centers where ever there has been any chance to initiate them. Computing center of Institute of Kinesiology and the University Computing Centre - SRCE illustrate that (Budin, Jurišić-Kette, Momirović, Peruško, Požar, Simović, Stefanini, Turk, 1974).

The importance of information systems in the fields of education and sports had been anticipated too. Several projects have been proposed: Information system of secondary education (Momirović, Aurer, Maćašović, Gredelj, Gospodnetić, Obelić, Hađina and Stipanović, 1979); Information system of physical culture (Momirović, Gredelj, Štalec, Gospodnetić Milonja, Pavičić, Semenov and Stipanović, 1979); and Information system of top level sport (Ambrožić, Ban, Gospodnetić, Momirović, Pavičić, Pedalo, Semenov and Štalec, 1983).

It has been realized very early on that collections of statistical and data analysis subroutines should be interrelated through general statistical language. So, the first version of SS (statistical system) appeared to be active on the base of close cooperation of Zakrajšek, Štalec and Momirović (1969). Initial versions of SS were developed and coded in FORTRAN IV for IBM 1130 at the Institute for Mathematics and Physics "Jozef Štefan" at the University of Ljubljana. By the year 1971 it was further developed and maintained at the Institute of Kinesiology at the College for Physical Education and at the University of Zagreb for IBM series 1130 and 370/165 of electronic computers.

Upgrading the computing facilities in Ljubljana (CDC Cyber) and in Zagreb (UNIVAC 1106) stimulated development of SS at Ljubljana and Zagreb. It went on for some time with cooperation and coordination. After 1974, further maintenance and development went on in Zagreb. SS Statistical system (Zakrajšek, Štalec and Momirović; 1974), the command (linear) programming language became ground floor for multivariate statistical data analysis explorations and education The basic kernel of SS was implemented in FORTRAN V language and systematically improved under the EXEC 8 operational system UNIVAC 1110 and UNIVAC1130 computers at the University Computing Centre - SRCE of the University of Zagreb.

In the period from 1976 to 1985 new algorithms were developed and numerous computer programs were written and implemented as ordinary scientific and educational tools in Zagreb methodological circle headed by SRCE. Most of these programs were realized in SS (Statistical System) programming environment (Figure 4). New developed algorithms Konstantin Momirović implemented along with his fellow researchers Marijan Gredelj, Vesna Lužar, Vesna Dobrić, Maja

Herak, Živan Karaman and Lajos Szirovicza from Universtiy Computing Centre - SRCE and Janez Štalec, Leo Pavičić, Ksenija Bosnar, Franjo Prot, and Nataša Viskić-Štalec from the Faculty of Physical Education.

At the time SS has been promoted and accepted as the key tool for multivariate statistical data analysis among potential users, members of the scientific community.

Supported by SRCE this multivariate data analysis program library SRCE*SS-MACRO had been used in various scientific and technical disciplines. Most frequently used macro programs could be classified as: analysis of non-numerical data (8 macro programs); metric (psychometrics, i.e. kinesiometrics) properties of measurements (5 macro programs); explorative and confirmative factor or component analysis (17 macro programs); taxonomic (cluster) analysis, pattern recognition and classification (8 macro programs); multidimensional scaling (11 macro programs); canonical correlation analysis, multivariate regression analysis, redundancy analysis and discriminative analysis (22 macro programs); stochastic process analysis and analysis of changes (7 macro programs).

Multivariate statistical analyzer (MSA) had been designed as a blue print of new version of Statistical system (SS), as a novel generation of specification language for multivariate data analysis and statistics with full set of nested logical and iteration program control structures (Momirović, Aurer, Maćašović, Gredelj, Gospodnetić, Obelić, Hađina and Stipanović, 1979; Momirović, Gredelj, Štalec, Gospodnetić Milonja, Pavičić, Semenov and Stipanović, 1979; Momirović and Štalec, 1983). Limited human resources and financial capacities stopped further development of SS Statistical System.

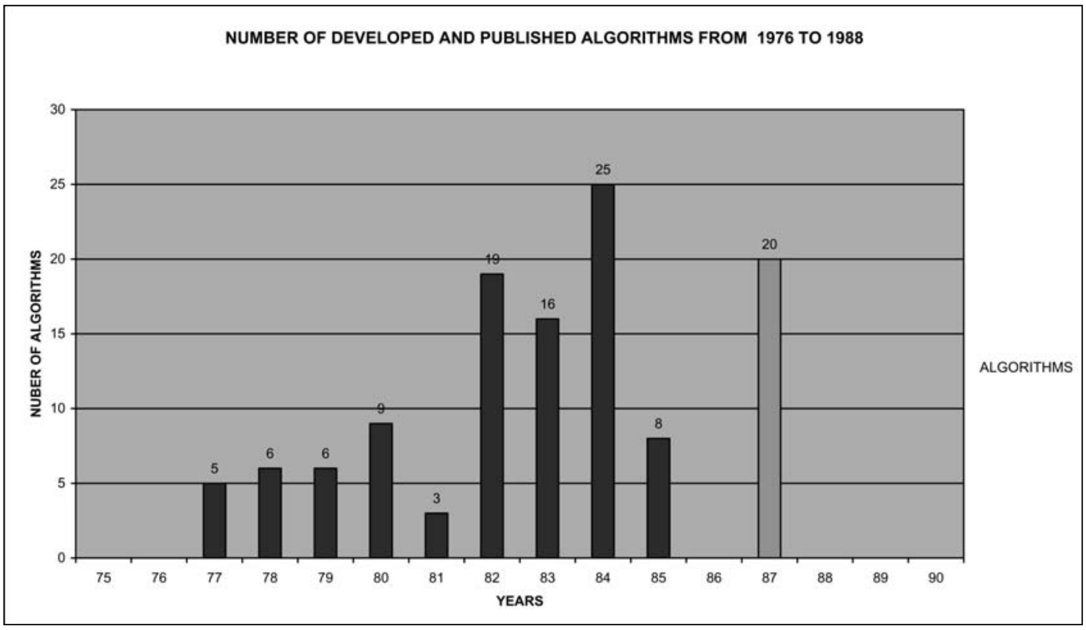

*Figure 3. The dynamics of creation, i.e. algorithm development for SRCE*SS-MACRO (1976-1985) and SRCE*GENS-MACRO library (1986-1990)*

In the period from 1986. to 1990. development and support of SS macro library was banned and further development was based on power and flexibility of GENSTAT system. Konstantin Momirović led a team of researchers (Marijan Gredelj, Vesna Lužar, Vesna Dobrić and Maja Herak, Ksenija Bosnar, Franjo Prot, Darko Dugić, Zlatko Knezović, Nataša Erjavec, Jovanka Radaković, Vesna Perišić, Josipa Kern) from the University Computing Centre - SRCE, Faculty of Physical Education and School of Public Health "Andrija Štampar" which established new public program library SRCE*GENS-MACRO on UNIVAC 1130 main frame computer (Figure 3). Most frequently used macro programs from SRCE*GENS-MACRO library could be classified into: analysis of non-numerical data (3 macro programs); metric (psychometrics, i.e. kinesiometrics) properties of measurements (2 macro programs); explorative and confirmative factor or component analysis (4 macro programs); taxonomic (cluster) analysis, pattern recognition, classification and discriminant analysis (5 macro programs); correlation analysis, canonical correlation analysis, multivariate regression analysis, redundancy analysis and discriminative analysis (26 macro programs); stochastic process analysis and analysis of changes (22 macro programs).

In the period from 1996 to 2004 Momirović devoted himself to design and development of a whole new macro library implemented in SPSS macro language as a library of macro programs "IKSI" at the Institute for Criminological and Sociological Research.

Algorithms and macro programs developed from 1996 to 2004 (Figure 4.) could be classified into 21 groups, as shown in Table 1.

In total there are 762 macro programs from which 703 are explicitly referred to as being designed, developed, and coded by Momirović himself (Table 1.). It is important to notice that 390 technical reports are referenced in these almost self documented macros. Technical reports are documenting methodological contributions.

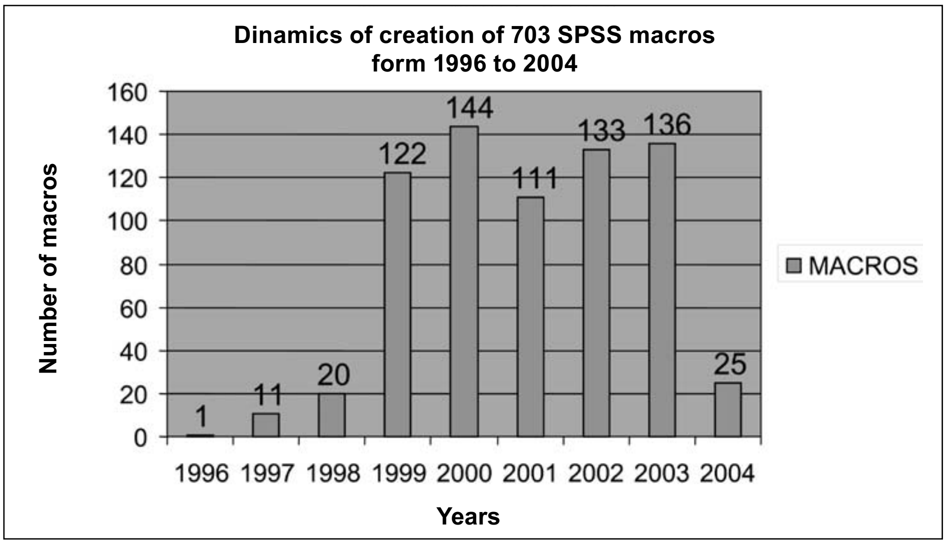

Figure 4. The dynamics of creation, i.e. algorithm development and SPSS macro coded programs (1996 - 2004).

The dynamics of creation of macro programs, i.e. algorithms between 1996 and 2004 demonstrate intensive and continuously high rate productivity for the last six years of his life.

Phenomenon of Konstantin Momirović's work on this macro library, along with 390 associate technical reports, as a part of his legacy in the field of multivariate statistics and data analysis is worth for further study.

Table 1. The distribution of SPSS macro programs coded by Momirović, classified in 21 program groups / areas of multivariate data analysis

PROGRAMS GROUP	No. of macro programs
(01) Analysis of metric characteristics of composite measurement instruments	46
(02) Component analysis	140
(03) Factor analysis	70
(04) Taxonomic analysis	51
(05) Metric multidimensional scaling	7
(06) Latent structure analysis	11
(07) Redundancy analysis	12
(08) Canonical correlation analysis	30
(09) Non-numerical data analysis	29
(10) Canonical covariance analysis	23
(11) Discriminant analysis	30
(12) Multivariate regression analysis	44
(13) Correlation analysis	22
(14) Analysis of qualitative changes	9
(15) Analysis of structural changes or structural differences	18
(16) Pattern recognition	9
(17) Emulation of neural networks	150
(18) Nuclear analysis	21
(19) Network analysis	4
(20) Descriptive and inferential statistical methods	21
(21) Auxiliary mathematical and statistical programs	24
T O T A L	771

Concluding remarks

Zagreb kinesiology circle have been developed around the contemporary science of human movement based on the methodological developments appropriate to the research problems imposed and resolved.

Konstantin Momirović, alias Stojan Hadžigalić, has been an active contributor to both theoretical and applied developments of multivariate data analysis from the early 1960s till his sudden death in 2004.

From the point of view of development of his ideas on multivariate data analysis, it is possible to recognize several phases. In the first, initialization phase, he worked on methodological topics as individual assimilating and developing contemporary ideas. His contribution to the design of SS Statistical System for multivariate data analysis prepared the ground floor the organized theoretical and applied team work. In the second phase, he influenced and became the originator and principal figure in the so called "Zagreb Methodological and Multivariate Data Analysis Circle at the University of Zagreb (Institute of Kinesiology at the Faculty of Physical Education and at the University Computing Centre - SRCE) where completely new ideas emerged. In the third phase he influenced and organized various productive groups of researchers around the Institute for Criminological and Sociological Research, and the Department of Psychology at the Faculty of Philosophy of University of Belgrade. That indicates that "circle" becomes an influential "school".

Methodological research and achievements after 1971 could be divided into the following three areas of data analysis:

1. Kinesiometrics (development of new theoretical and applied measurement models in the field of measurement theory)
2. Multivariate data analysis and statistics (new models, methods and algorithms for data analysis)
3. Informatics (a field of computer science related to the development of new software for information systems, data analysis and management)

Evolution of some ideas, algorithmic solutions and programs implementations are evident. The contributions and experiences are finally divided as they are grouped and incorporated in the SPSS macro language coded library of more then seven hundred macro programs. Further research is needed to enable better understanding of the complexities of his ideas implemented in macro programs, especially where artificial neural network approach to multivariate data analysis problems is integrated.

This rather short and illustrative overview is just a preliminary attempt to the deeper insight into phenomenon of Konstantin Momirović's work and his legacy in the field of multivariate statistics and data analysis as foundations of research methodology and methods in kinesiology.

References *

1. Anderson, T.W. (1958): An introduction to multivariate analysis. First edition New York: Willey.
2. Anić, V., I. Goldstein (1999): Foreign Words Dictionary (Rječnik stranih riječi). Zagreb: Novi liber (in Croatian).
3. Bock, D.R.(1975): Multivariate Statistical methods in behavioral research. New York, McGraw-Hill Book Company.
4. Bujas, Z., B. Petz, M. Mraković (1983): Report of 15/04/1983 for the nomination as full professor of "Quantitative Methods" (Professor K. Momirović), Faculty for Physical Education, University of Zagreb (in Croatian).
5. Cattell, R. B. (1966): *Handbook of multivariate* experimental *psychology.* Chicago: McNally.
6. Cooley, W. W.; Lohnes, P. R. (1971): *Multivariate data analysis.* New York: Wiley.
7. Dobrić, V. (1986): On a class of robust methods for multivariate data analysis. In: COMPSTAT 1986. Proceedings in Computational Statistics, Physica-Verlag, Heidelberg: 211-216.
8. Fajgelj, S. (2004): In memoriam Konstantin Momirović 1932-2004. Psihologija (Psychology), 37, 2: 219-225.
9. Guttman, L. (1945): A basis for analysis test - retest reliability. *Psychometrika*, **10**: 255-282.
10. Guttman, L. (1953): Image theory for the structure of quantitative variates. *Psychometrika*, **18**: 227-296.
11. Harris, C.W. (1962). Some Gutman-Rao relationships. Psychometrika, 27: 247-263.
12. Harman, H.(1960) Modern factor analysis. Chicago: University of Chicago Press.
13. Harman, H (1967) Modern factor analysis. 2nd edition.Chicago: University of Chicago Press.
14. Hljuz Dobric, V., F. Prot, V. Luzar-Stiffler, Z. Bekic, K. Bosnar, M. Gredelj (2008):. Konstantin Momirović (1932-2004) Memorial Session: *Data Mining, Statistics and Biometrics.* In: Luzar-Stiffler, V., V. Hljuz-Dobric, Z. Bekic. *Proc. ITI 2008 30th Int. Conf. Information Technology Interfaces.* Zagreb: University Computing Centre – SRCE, pp. 3 (CD version: IEEE Cat.No. CFP08498-CDR; ISBN 978-953-7138-13-4; ISSN 1334-2762).
15. Hopfield, J.J. (1982): Neural networks and physical systems with emergent collective computational abilities. *Proceedings of National Academy of Sciences*, 79:2554-2558

* *Full list of references can be found in: Prot, F., A. Hosek, K. Bosnar, V. Luzar-Stiffler, V. Hljuz Dobric, Z. Bekić, M. Gredelj (2008). Konstantin Momirovic (1932-2004): Biography and Bibliography.*

16. Horst, P. (1965): Factor analysis of data matrices. New York: Holt, Rinehart & Winston.
17. Vlahović, P.; P. Kovačević (2005): In Memory of Prof. Dr. Konstantin Momirović (1932-2004), (in Serbian) Pro Memoria Prof. Dr. Konstantin Momirović: 13. January 1932 - 28. March 2004. Belgrade: Glasnik antropološkog društva Jugoslavije (Revue de la Societa Anthropologique de Yugoslavie), 40:43-46 (in Serbian).
18. Kaiser, H. F.; Caffrey, J. (1965): Alpha factor analysis. *Psychometrika*, **30**: 1-14.
19. Kaiser, H. F. (1970): A second generation Little Jiffy. *Psychometrika*, **35**: 401-415.
20. Kališnik, M., J. Goričar, D. Ulaga (1979): Report of the Nomination Committee on K. Momirović full professorship for the course "Kinesiological Methodology" at the Physical Education College in Ljubljana (in Slovenian).
21. Krković, Anđelko; Momirović, Konstantin; Petz, Boris (1966): Selected chapters from psychometrics and nonparametric statistics. Zagreb: Croatian Society of Psychologists, pp. 120 (In Croatian).
22. Lužar, V. (1985): Inference in quasicanonical correlation analysis. *Proc. 7th International Symposium "Computer at the University",* Zagreb: University Computing Centre - SRCE, 518: 1-6.
23. Macura, D. (2004): In memoriam Konstantin Momirović (1932-2004), Šport (Sport), 2004: 52-53.
24. Momirović, K. (1963): Factor structure of neurotic symptoms. PhD Thesis, Faculty of Philosophy, University of Zagreb (in Croatian).
25. Momirović, K. (1972): Applied Kinesiology - Short course in Kinesiometry. Lecture notes M.Sc. study in Kinesiology, year 1971/72. Zagreb: College for Physical Education, pp. 88.(in Croatian).
26. Momirović, K. (1976): Biography and Bibliography within the Application for lectureship on the course "Kinesiological Methodology" (Narodni list SRS, 25.12.1976), at the Physical Education College in Ljubljana (in Slovenian)
27. Momirović, K., B. Aurer, P. Maćašović, M. Gredelj, R. Gospodnetić, V. Obelić, Hađina and R. Stipanović, (1979): Information System of Secondary Education in Croatia. Zagreb: University Computing Centre - SRCE (in Croatian).
28. Momirović K., M. Gredelj, J. Štalec, R. Gospodnetić, Z. Milonja, L. Pavičić, I. Semenov i R. Stipanović (1979): Conceptual project of Information System for the Croatian Psysical Education and Sports. Zagreb: Faculty of Physical Education, (12 books, in Croatian)
29. Momirović, K. (1989): Biography for the "Ramiro Bujas Award 1989", Zagreb: Croatian Society of Psychologists (in Croatian).
30. Momirović K., J. Štalec, E. Zakrajšek (1982): A programming language for multivariate data analysis. *COMPSTAT 82, Proceedings in Computational Statistics - Part I, Physica Verlag, Wien*: 87-95.
31. Mulaik, S. A. (1972) Foundations of factor analysis. New York, McGraw-Hill Book Company.
32. Prot, F. (2004): In memoriam prof. dr. Konstantin Momirović (1932-2004). Unpublished manuscript submitted to "Primjenjena psihologija" (Applied Psychology), (in Croatian).
33. Prot, F. and K. Bosnar (1988): An algorithm and program for the analysis of individual changes based on absolute and relative measures of change. *Proc. 10th International Symposium "Computer at the University",* Zagreb: University Computing Centre - SRCE, 5.4: 1-5.
34. Olkin, I. (2008): In memory of Konstantin Momirović 1932-2004. *Proc. ITI 2008 30th Int. Conf. Information Technology Interfaces*, Zagreb, University Computing Centre – SRCE, 309-310.
35. Prot, F., K. Bosnar, M. Mraković (2004): Research methodology in Kinesiology. In Jaklinović, Ž. et al, Editors (2004): Materials for Bibliography, Faculty of Kinesiology 1959 – 2004. Faculty of Kinesiology, Zagreb: 24-37 (in Croatian).
36. Prot, F., A. Hošek, K. Bosnar, (2008): Prof. dr. Konstantin Momirović (1932-2004): Contributions to Biography and Bibliography, pp. 85 (Unpublished manuscript, in Croatian)
37. Prot, F., A. Hosek, K. Bosnar, V. Luzar-Stiffler, V. Hljuz Dobric, Z. Bekić, M. Gredelj (2008): Konstantin Momirovic (1932-2004): Biography and Bibliography In: Luzar-Stiffler, V., V. Hljuz-Dobric, Z. Bekic. *Proc. ITI 2008 30th Int. Conf. Information Technology Interfaces*, Zagreb, University Computing Centre – SRCE, pp.200 (CD version: IEEE Cat.No. CFP08498-CDR; ISBN 978-953-7138-13-4; ISSN 13342762).
38. Rao, C. R. (1952): Advanced statistical methods in biometric research. New York: Wiley.
39. Rao, C.R. (1973) Linear statistical inference and its application. New York: Willey.
40. Šipka, P. (2005): Social Studies in Serbia, with and without Momirović: a bibliometric portrait. Psihologija (Psychology) , 38, 3: 345-360 (in Serbian).
41. Štalec, J., K. Momirović, E. Zakrajšek (1982): Programming in SS: Description of a set of macro programs for multivariate data analysis. *COMPSTAT 82, Proceedings in Computational Statistics - Part II, Physica Veralg, Wien*: 251-252.
42. Zakrajšek, E., J. Štalec, K. Momirović (1974): SS – A System of Programs for Multivariate Data Analysis, *Proc. 1st Int. Sympsium "Computer at the University",* Zagreb: University of Zagreb, University Computing Centre - SRCE, C8:1-16 (in Croatian).

Acknowledgements

This research was partially supported by the Ministry of Science, Education and Sport of the Republic of Croatia, through the SScientific Research Project No. 034-0342618-2222 "The Development of Algorithms for Multivariate Structural Hypotheses Testing", Principal Investigator: Franjo Prot.