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Theoretical Biomechanics: Design of the Associated Measurement Symmetry System

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Abstract

Based on the own experience of the authors and the literature, an original proposition of the device and system software based on the quotient scale was presented, where the mutual relations of parameters from several or several simultaneously working measuring devices are easily visible on a common graph in real time. The project is connected with an outline of problems of musculo-skeletal system diagnostics, aiming at creating a universal, systemic parametric graph, defining in parallel-multi-parametric and quantitative manner, the patient's initial health profile as a set of parametric symmetries (or asymmetries), having specific and separate characteristics for healthy individuals in all age groups, as well as in groups with specific disease units. The directional pattern for Authors, aiming at the systemic recognition of the causative phenomena and the consequences of motion in the form of a multi-parameter graph calibrated by a common time axis is the way of electrode location, recording and parameterization of the ECG curve. This universal formula, defining parametrically the problems of evolutionary and involutionary norms, as well as most known pathologies, has become the foundation of cardiology, functioning worldwide over the language barrier.

Keywords: AMSS, parametric symmetries, quotient scale, systemic multiparametric graph

1. Design of the associated measurement symmetry system

The questions posed above express doubts and searches of many specialists in the field of biomechanics - anthropometrics in particular. Initiation of the associated measurement symmetry system (AMSS) was an attempt not only to answer the above questions but also to draw attention of the medical and scientific community involved in the study of the musculoskeletal system, to the need to search for a universal standard (protocol) and a multiband system for evaluation of the structural and motor characteristics of the body. The analysis of the existing measuring instruments clearly indicates that in order to simultaneously use several measurement methods, each of which has originally different system of units (on an interval scale), we are not able to assess the interparametric relationships in real time, and possible relationships between parameter trends can be expressed with a long delay, by means of using statistical tests only. In this situation, a good and

expected solution would be to illustrate on one graph, calibrated with one time stamp (in a selected, universal frame of reference), a whole range of parameters, starting with the traditional vector features of motion, with attached, parallelly registered causative parameters of motion, e.g., rheological, impedance, and magnetic, as well as parameters of physical effects of motion on the ground (strain gauge measurements) and electrodiagnostic imaging and psychometrics. Reflecting on one correlated graph, the phenomena of parameter symmetry for parallelly used measurement techniques (or with a slight time shift) provide a unique opportunity to formulate static and dynamic motor standard of the body, containing the parameters of the specific psychometric and electrogalvanic predispositions, resulting in the creation of a time-space distribution of motion vectors and also the temporal-spatial distribution of gravity vectors in the area of contact of the limbs with the ground [1–4].

The use of the quotient scale allows to incorporate into the system almost every research method, in a manner that refers to the symmetrical construction plan of the musculoskeletal system (and many internal organs) or, in other words, to measure the mirror areas of the left and right upper and lower limbs and trunk. The consequence of this action is determining the nondimensional representation (coefficient) for the symmetry of a measurement pair in the field of a specified physical quantity, presented as a symmetry, asymmetry, or lateralization indicator, whose value is in the range of 0–1.

The next part of the work presents the author's design of a device implementation, along with the base of a systemic software based on the quotient scale, where interactions between parameters derived from several concurrent measurement devices are easily visible on one graph in real time. It should be noted that the basic feature of the quotient scale—auto-calibration and the absolute zero associated with it—allows for a simple presentation of dynamic and structural symmetry (reflecting the state of balance) and asymmetry phenomena (reflecting the state of dysfunction). It is also worth to notice the advantages lying in the practical aspect, namely, great ease to compare or even convert data from measurement systems based on the interval scales. For this purpose, the system will be equipped with an interface, allowing for a systemic application of data from devices which show results in the interval scales. The adoption of a universal, multiparametric quotient scale to illustrate the results of instrumental research and to associate it with known, clinical criteria of a medical examination may be an introduction to the formulation of more strict definitions of the patient's condition at the stage of diagnosis, the subsequent stages of treatment, as well as the determination of the recovery criteria (in relation to the parameters of the group standard).

Another issue is the need to develop the technical standard of the device and the measuring points, lying on the body's subsequent levels in a standing position—for easier visualization, they were called transverse measurement planes (TMP), with a strict location for each type of measurement (like the location of the electrodes in the ECG). The output standard should contain a set of horizontal measurement planes and a scheme of their vertical correlations. The next part of the implementation is a standard procedure for testing medical devices, which involves, among others, developing a standard of population norms, in the first phase for healthy individuals (including sexual dimorphism and the process of involution in several standard age groups). In the second phase, after selecting diseases of the locomotor system with particularly specific criteria for the clinical diagnosis, they should be expanded by a formal description of symmetry in standard measurement planes of geometric, kinematic, rheological, thermal,

electrical, and magnetic features, whose classification (and then unification) will give the chance to formulate a concise statement setting out the state of parametric symmetry (or asymmetry) of patient's organism, as compared to the group norm, pathology pattern of a disease unit, or comparatively, between the initial state and the next stage of the therapy. Following the above in relation to disease units with specific diagnostic criteria, one can think of attributing sets of relevant coefficients of asymmetry to them, thus enriching the diagnostic criteria with a quantitative dimension. A desired, but still unsurpassed, standard to be followed by locomotor organ diagnosticians should be the topographic-parametric formula of registering in ECG, which FUNCTIONS OVER THE SYSTEM AND LANGUAGE BARRIERS WORLDWIDE.

In experimental studies conducted among large groups of students and health-care professionals, a repeatable and close relationship between structural symmetry coefficients and symmetry of marker dynamics was observed, and above all, with the coefficients of changes in tissue perfusion, their temperature, resistance, and magnetic induction. The high repetition of the symmetry trend observed in subsequent age groups and the diverse asymmetry in the population of patients raises the hope of creating reliable norm standards for involution phenomena and selected types of pathology.

1.1 Searching for one scale for the symmetry phenomena

Presentation of a global, multiparameter body description on a single graph, which allows simultaneous display of coexistence and correlations between the dominant parameters describing patient's condition, on the one hand requires focusing on the clinical phenomena, which are the most important in this case, and, on the other hand, converting all results registered in a variety of disease units—to one, universal scale.

1.2 Measurement and measuring scales

The measurement is a procedure of associating the features of the examined objects with numbers or other symbols according to specific rules for which (1) the relationship between the numbers and features subject to measurement must be exclusive, (2) the rules for assigning number features should be standardized and applied uniformly, and (3) these rules must not change in relation to the objects and time. The next step is scaling, i.e., creating a continuum on which numerically measured object features are placed. This enables measuring, i.e., assigning to each tested object a strictly defined number within the range of the scale used. Among the scaling techniques, there are (1) comparative scales that allow direct comparison of the features of the examined objects in relative categories and are ordinal or rank and (2) noncomparative scales, for which each object is scaled independently of the others in the examined set, while the results are interval or quotient. Despite the benefits of using comparative scales, such as a common reference point and the ease of detecting small differences between the tested objects and a small number of theoretical assumptions, they have significant disadvantages, which include the ordinal nature of the data and the resulting inability to approximate results outside the population of the scaled test objects.

The quotient scale is the most versatile, because it has all the properties of a nominal, ordinal, and interval (fixed unit) scale, allowing for precise calculation of relationships between the scale values, for which all proportional transformations are permitted. The most important of its advantages, not occurring globally

in other scales is a non-arbitrary “0” point on the scale, is the so-called absolute zero, giving the possibility of estimating not only the symmetry of parameters measured by a common unit but primarily a comparison (on one frame of reference) of measurement trends, based on units that are significantly different in their specificity, and virtually using all statistical techniques. Quotient scale, as the most versatile, has all the properties of nominal, ordinal, and interval scale, enabling precise calculation of relationships between the scale values, for which all proportional transformations in the form of $y = bx$ (where b is a positive number) are allowed.

Typization is the process of ranking elements of reality into certain types by referring to existing knowledge resources, preferably parametric (Schütz). A specific element of the surrounding space is treated as similar, provided that the construction and parametric criteria typical of the previously created and known set of features are met. This procedure is an expression of the use of economic simplifications in the classification of objects. Getting to know the surrounding space, you first perceive the general features typical of the class of the object and only then focus on the details. A certain analogy, in particular for the creative process, is standardization, i.e., the activity of analyzing and giving new procedures and innovative products’ parametric repeatability to ensure compatibility and limit unnecessary diversity. Profiles of standardized products are made public in the form of standards, technical regulations, or recommended parametric standards (e.g., SI).

The idea of typing for a measuring system is reflected in **Figure 1**, where each of the measured parameters is presented as a plane built into the patient’s standard silhouette, on which the lateralization coefficient is determined, which is a reflection of the local parametric symmetry determined on the basis of sensor indications applied at standard marker points. The quotient of these values gives a lateralization

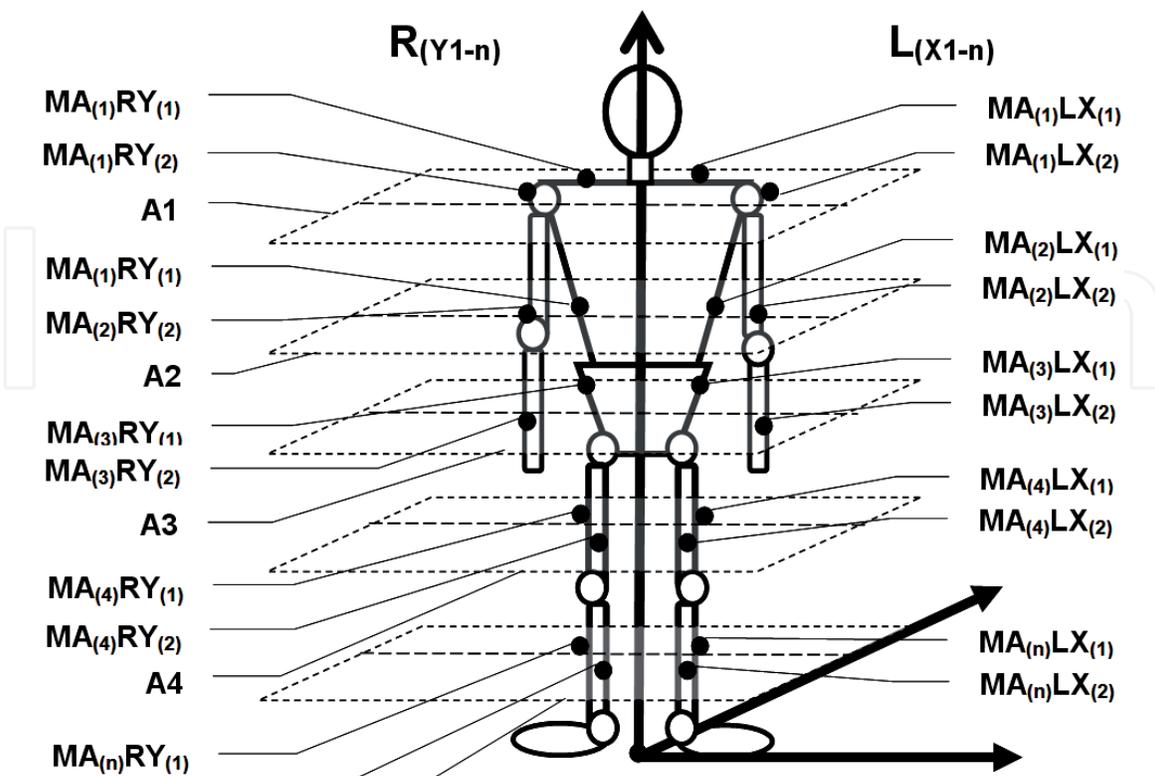


Figure 1. The layout of marker symmetry on AMSS measurement planes according to the P402850 patent application in the Polish Patent Office, entitled “Method of formulating parametric, diagnostic-therapeutic criteria with an algorithm and device for its implementation”.

coefficient, the value of which can depict the symmetry or asymmetry of a given parameter on a common quotient scale. Based on population surveys, mean and reference values as well as the range of standard deviation of results can be determined in subsequent age groups.

1.3 A summary of the project features

While developing the author's concept of anatomical-functional parameterization of symmetry, attention was drawn to the subsequent stages necessary for implementation [5]:

1. Introduction of (employed by us) anatomical standard agreed on transverse measurement planes of the body $A_{(1...n)}$ (**Figure 2**) in order to determine symmetric left-hand $MA_{(1...n)}L_{(x1...n)}$ and right-hand $MA_{(1...n)}P_{(y...n)}$ markers – their location quite naturally prompts a conversion of any interval parametric scale (exemplary units: V, mA, Ω , μ m, T) to symmetry and asymmetry indices on a quotient scale, which may reflect symmetry or asymmetry of both, selected features of static images (photography, radiography, and microdensitometry), anatomical structure of twin body organs (joints, bone parts, and points of silhouette contours), dynamic images (quadroscopy and X-ray seriography), and recordable spontaneous (thermography, magnetography, and electrography) and forced emission phenomena (scintigraphy, gammagraphy, and SPECT). It also applies to contact recording of dynamic (accelerometry, gyrometry, and tensometry), electrical (EMG, ENG, EEG, EOG, and PCP), and magnetic phenomena, as well as rheological parameters in symmetrical points of the vascular system (plethysmography, Doppler-USG, angio-CT, and angio-MR).

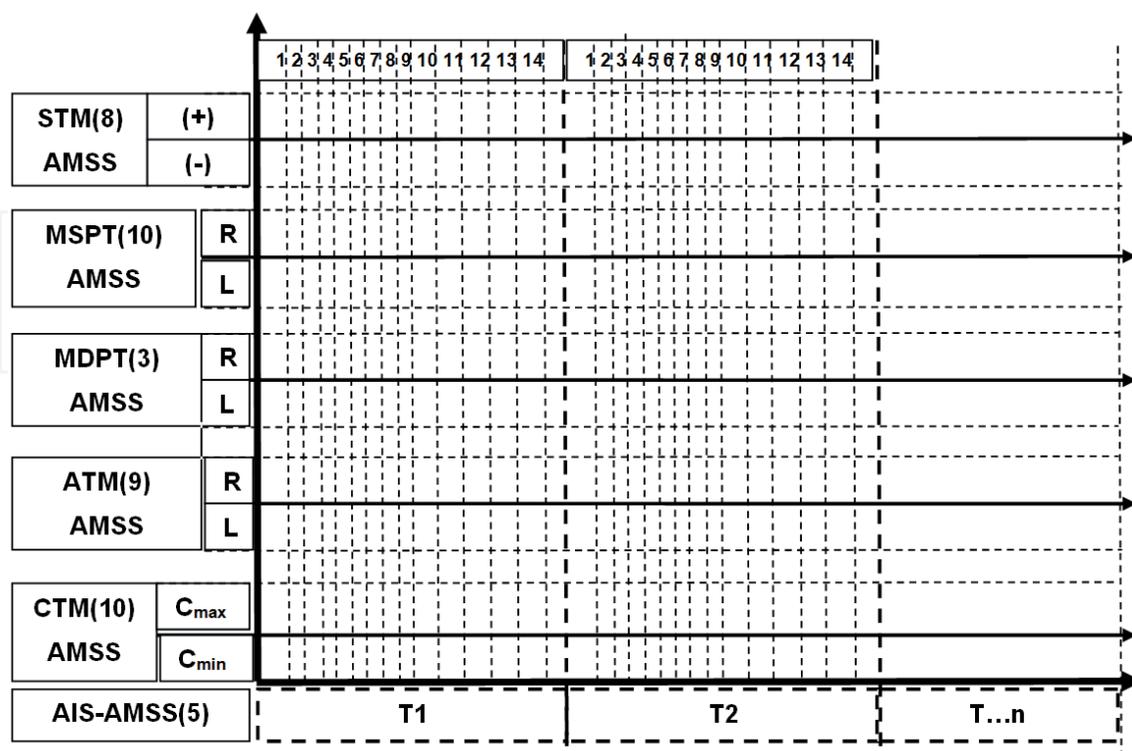


Figure 2. Exemplary construction of a measurement graph with indication of lateralisation direction (R/L), type of the test (STM—survey tests, MSPT—static planimetric tests, MDPT—dynamic planimetric tests, CTM—biometric tests, ATM—biochemical tests) and sequence of time stamps.

2. In such a constellation, a parametric motion profile (as a single or one of many described functions) of a healthy individual is in fact a sum of (developed over time) parallel sequences of quotients of parameter symmetries ($x \approx 1 \pm 0.1$), calculated individually (as simple or alternating indices) on the basis of data from the left-hand $MA_{(1...n)}L_{(x1...n)}$ and right-hand $MA_{(1...n)}P_{(y...n)}$ markers located in twin, anatomically characteristic (agreed on) points of the transverse measurement planes of the body $A_{(1...n)}$ (**Figure 2**), while the motion dysfunction in this approach is a sum of parallel, asymmetric sequences ($x < 0.9$ lub $x > 1.1$), for the parameters calculated on the basis of the above standard of markers (**Figure 2**).
3. The results, presented as the (developed over time) quotient scale coefficients, are subject to the laws of statistics, in particular to the correlation calculus, which searches for parametric constellations particularly relevant for dysfunctional syndromes accompanying specific disease syndromes.

2. The associated measurement symmetry system (AMSS)

Detailed assumptions and relevant design parameters of the AMSS original idea have been included in the documentation of patent application P402850, entitled “Method of associating results of several research methods as well as algorithm and device for its implementation” [5].

2.1 Introduction

It is very interesting for any practitioner involved in the diagnosis and treatment of the musculoskeletal system to be able to make a quick and direct measurement of selected characteristics of the geometry of motion vectors and stabilometric posture features against the causative motion parameters (psychometry) and the consequences of movement, among others, contourography, tensometry, accelerometry, electrosensometry, multi-point thermo- and plethysmography, electromyography, nerve conduction, diagnostic imaging parameters, and even psychometric diagnosis of the patient. Implementing this direction of research at LABIOT, at the turn of 1999 and 2000, many clinical tests successfully used a 12-channel system of accelerometer sensors for the analysis of the California gait markers, sensors for the assessment of the respiratory tract, the Lasegue and Yeoman’s test, recording the oscillations of selected marker bodies in specific clinical and kinematic states. The advantages of such a configured system have been confirmed in large-scale clinical tests [6, 7]. To meet the need of standard repeatable, optimized measurements of static and dynamic parameters of the human body, and on the basis of them, for an introduction of criterialization of an upright posture and selected dynamic features, it was attempted to group diagnostic tools on a computer platform [8–15], which enables obtaining multidimensional, psychological, planimetric (static), posturometric, and dynamic determinants and thereafter their registration in one database (with a unique ID for each patient). The resulting data is presented on a quotient scale, in the case of biochemical and psychological tests as indicators of the upper or lower limit of the norm, while in the case of planimetric and bioengineering tests as indicators of lateralization. These phenomena have been studied in laboratory and clinically in the succeeding years and were described in the following publications [1, 16–18].

2.2 The essence of the AMSS system

The essence of the AMSS is the method of formulating parametric diagnostic and therapeutic criteria as well as the algorithm and device for its implementation. The purpose of AMSS is to parametrically reflect health and disease (with specified criteria) using the results of simultaneously used research methods that may differ significantly in the dimensions of the physical units used. The method and algorithm give the opportunity to present all test results on a common time axis, preferably on a quotient scale in the form of a graph consisting of dimensionless coefficients related to symmetry, or the minimum or maximum reference value adopted for a specific measuring method (in particular laboratory). This way of recording, processing, and simultaneous presentation of the results of known and commonly used measurement methods opens the way to obtaining a new type of numerical criterion graphs illustrating the state of health and unambiguously pathological criteria. The criterion graph can also be presented in a reduced form using inter-parameter correlation indicators.

The AMSS system, using electronic, algorithmic, and software criteria, allows for the following:

1. Simultaneous, multidimensional recording of biomedical data and their conversion into quotient coefficients, recorded with a time stamp
2. Processing of static, geometric features of body images made with any imaging technique to form symmetry quotient coefficients, recorded with a time stamp
3. Processing of dynamic, geometric features of body images made with any technique to form quotient coefficients associated with symmetry as well as with time marker and path
4. Processing of numerical values for substance concentrations determined “in vivo” and “in vitro” into quotient coefficients that are correlated with the maximum and minimum reference concentration and with a time stamp
5. Processing of numerical results of psychological tests to form quotient coefficients that are correlated with the maximum and minimum value of the reference test and a time stamp

Patient's condition can be registered on the large-format medium (e.g., phone memory card—20 GB) and coupled with a sequence of globally or zone synchronized time stamps (T) as a set of simultaneous, multi-track test results, reflecting the characteristics of the structure and function of the body: (1) quotient indicators (of lateralization), for measurements performed within the markers of symmetrical body parts, and (2) quotient indicators in relation to the maximum or minimum value (for results of questionnaire and laboratory tests).

The purpose of using quotient factors is to create the possibility of the following:

1. Converting the measurement results initially presented using various interval scales to a common denominator, the ratio of the quotient scale
2. Presentation of many, even several dozen parameters of the quotient scale on a common chart using a time stamp to clearly define time relations for interparametric correlation coefficients

3. The application of the numerical values of the above coefficients to form a measurement graph, i.e., a sequence of graphical and parametric symbols that reflect the state of the organism (S), for (n) parameters, recorded with a time stamp (T) (**Figure 2**)
4. Application of the idea of a measuring graph to determine a standard profile graph, for neonatal [GPS (n)], children (2–8 years) [GPS (d)], adolescent (9–14 years) [GPS (m)], juvenile (15–20) [GPS (md)], adult (21–30) [GPS (d1)], adult (31–40) [GPS (d2)], adult (41–50) [GPS (d3)], adult (51–60) [GPS (d4)], involutionary (61–70) [GPS (i1)], involutionary (71–80) [GPS (i2)], senile (81–90) [GPS (s1)], and old age (91–100) [GPS (s2)]
5. Application of the measurement graph idea to determine the sport profile graph [GPS (s1–n)] for athletes in disciplines from 1 to n
6. Application of the measuring graph idea to determine the professional profile graph, in particular for special occupations, e.g., commando [GPZ (ks)], diver [GPZ (n)], pilot [GPZ (p)], and astronaut [GPZ (ka)]
7. Application of the measurement graph idea to reflect the criteria of pathologies of well-verified and characteristic disease entities in order to obtain a dysfunction profile graph [GPD (p1–n)]
8. Determining the progression trend for the dysfunction profile graph (worsening of disease symptoms on the time axis) or regression trend (disappearance of disease symptoms until reaching the standard or sport profile graph in a given age range)

2.3 The structure of the AMSS system

The central element of the system is the CME-AMSS electronic central module, which has at least four groups of I/O ports, enabling data download between peripheral devices and program modules (1–5). The system is controlled by the PP-AMSS measuring software platform implemented in the “DELPHI 7.0 professional” environment, having (1) the BW-SSSP benchmark database; (2) the BWW-AMSS results database, available by patient ID; the SSI artificial intelligence system base-AMSS; as well as a database of tool modules, containing:

1. **TA-AMSS survey test module** is a collection of computer questionnaire tests, in particular psychological and quality of life scales, selected as useful for medical diagnostics, according to the algorithm for creating baseline assessment, assessment during and after treatment. In practice, intelligence tests (Stanford-Binet test, Raven matrices), personality and interests test (Mittenecker-Thoman) and language predispositions, depression tests (BDI, MADRS, HADS, Hamilton), and tree projection test were used.
2. **Planimetric static test module PTS-AMSS** is a computerized package of software tools for automatic planimetric measurements on static files of radiological, scintigraphic, ultrasound, and thermographic images (main location of 2D, 3D points, distance, angles). The use of these easy-to-use measuring tools, and through them the use of a lot of planimetric operations, gives the possibility of creating numerical equivalents of specific elements of the matrix of any image of biological structures. To improve the functionality of the system,

measurements should be made on a matrix of symmetry markers, enabling the acquisition of specific lateralization indicators.

3. **The PTD-AMSS dynamic planimetric testing module** is part of the PP-AMSS software platform intended for the acquisition of measurement data from devices connected to the central CME-SSSP electronic device for extracorporeal measurement of body movements and its anomalies, in particular enabling parametric evaluation related to movement marker drift, recorded as the sum of parallel asymmetric strings marked with a time marker.
4. **The MNA-AMSS analytical tool module** is part of the PP-SSSP software platform intended for the acquisition of measurement data from the CME-SSSP central electronic module connected via an analytical interface. It connects with devices for extracorporeal measurement of sample parameters, mainly body fluids and cells, as well as for measuring physicochemical parameters measured by applicators having direct contact with the examined tissues of the treated patient.
5. **The MTB-AMSS biometric testing module** is part of the PP-AMSS software platform intended for the acquisition of measurement data from dynamic measurement devices connected to the central CME-AMSS electronic module that has a direct contact with the patient's tissues (e.g., plethysmography, pulse oximetry, EEG, ECG, EMG, magnetometry, resistometry and resistive tomography, accelerometry, gyroscopy, impulse perception threshold assessment).
6. **The module of artificial intelligence systems SSI-AMSS** allows, depending on needs, the use of advanced inference systems to perform (a) erosion of the information stream without loss of relevant content, (b) thematic organization of information, (c) diagnostic inference based on decision support systems (hypothesis generators), and (d) inferences based on expert systems and (e) determining the numerical dimension of disease progression and remission trends (under the influence of treatment). A large amount of collected data is connected with the problem of their effective processing, aimed at obtaining cross-sectional knowledge about the studied phenomenon. In medical diagnostics aided by computer methods of data analysis, making the right decision is extremely important because it is about time, life, and costs of patient treatment.

Broadly defined, clinical metrology parameterizes the natural (and test), structural, physicochemical, biomechanical, and behavioral characteristics of the patient in the state of health and disease, giving the possibility of assigning the above features to numerical indicators that facilitate the criteria for health status, specific disease entities, as well as stages of treatment (progression/regression) disease. In our opinion, one of the most important, yet useful, features that facilitate assessment of the clinical state is determining (on the quotient scale) multiparameter lateralization indices, i.e., symmetry disorders in marker points of the twin body structures and presenting the degree of their asymmetry on one, multiaxial graph, where OX axes are time stamp calibrated. According to the authors, this is the first real and moderately expensive method, enabling simultaneous, global multipath view of the patient with the clinical symptomatology of a specific disease syndrome, comparing the subjectively perceived image from the diagnostician with the parameterizing broadband graph of disease asymmetries. It is worth adding that the subjectivity of the patient with whom the interview is collected is partially verified by the TA-AMSS test suite (**Figures 3–7**).



Figure 3. Award for the idea and construction scheme of the AMSS at (a) the 7th International Congress of Polish Rehabilitation Society (Łódź 2010) and (b) the gold medal of the 26th Physical Medicine and Rehabilitation Fair in Łódź 2019, for the device - PSB1 posturometer to implement the assumptions from 2010.

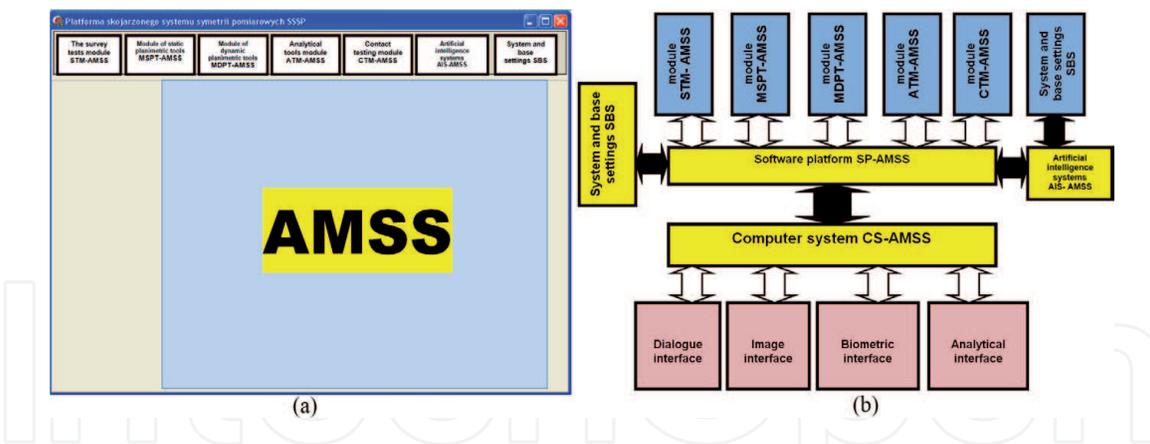


Figure 4. The main dialogue box of the AMSS system (a) SP-AMSS, connected to a computer system module (b) CS-AMSS, having the dialogue interface, image interface, biometric interface and analytical interface.

2.4 The stream of measurement data

The possibility of using increasingly sophisticated methods for recording parameters of subtle vital functions reveals an increasingly important issue of time interdependence of monitored parameters in clinical metrology. It is not of course of great importance when a single measurement of individual RR, HR, and temperature parameters is made. The possibility of multi-track data recording offered by rapidly developing metrological techniques meant that, together with the sensitivity and scope of monitoring and recording of parallel life functions, the relationship of their instantaneous values with time synchronization on the scale of the whole organism increases. The study of the temporal variability of

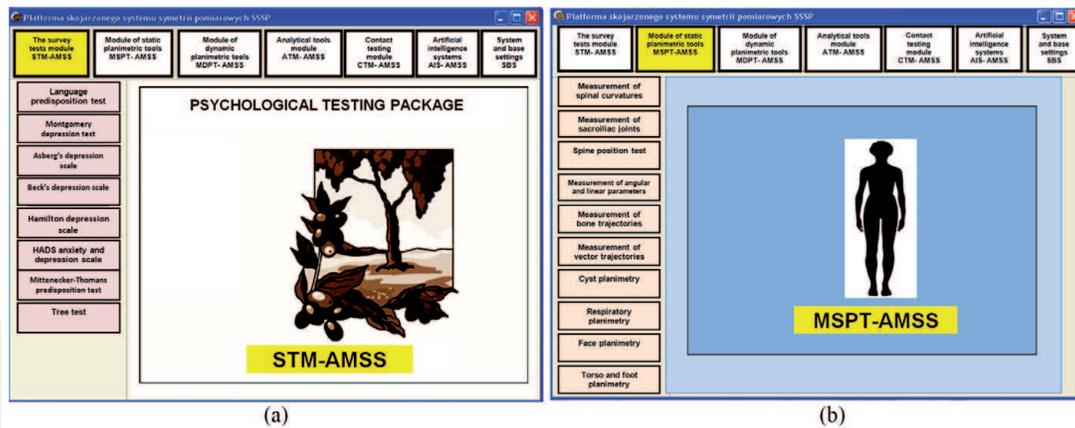


Figure 5. The software platform SP-AMSS consists of (a) survey tests STM-AMSS (particular psychological and quality of life scales) cooperating with the dialogue interface and the image interface, (b) static planimetric tests MSPT-AMSS (package of utility programs for automatic planimetric measurements on files with static radiological, scintigraphic, ultrasound, and thermographic images) cooperating with the image interface.

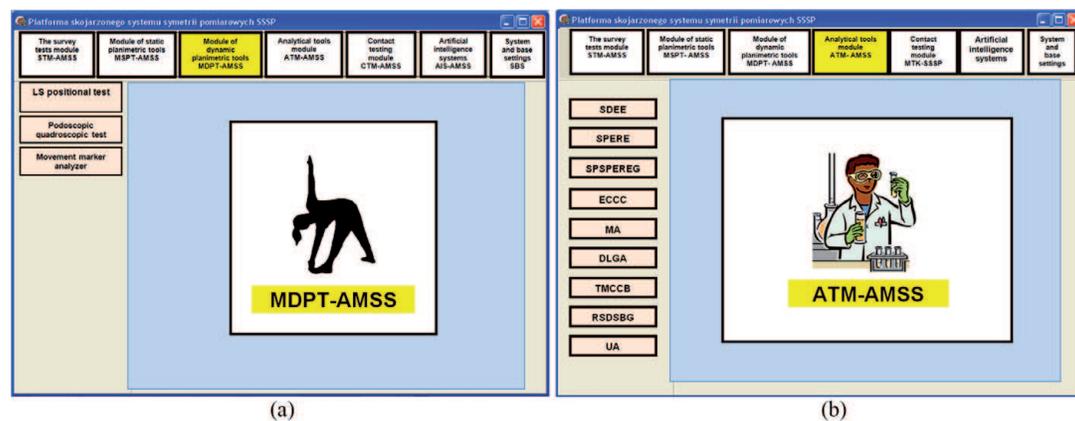


Figure 6. The software platform SP-AMSS consists of (a) dynamic planimetric tests MDPT-AMSS for the parametric evaluation of movement-associated marker drift, cooperating with the image interface and (b) analytical tools ATM-AMSS (with analytical interface to communicate with devices for extracorporeal measurement of sample parameters, particularly body fluids and cells). Devices in (b): SDEE—separator for dynamic centrifugal and electromagnetic electrochromatography (PL 171643); SPERE—separator for separation of particles by electrophoresis in rotational electromagnetic gradient (PL187203); SPSPEREG—separator for particle separation by phonoinductive electrophoresis in rotational electromagnetic gradient (PL 186372); ECCC—electromagnetic controlled column chromatography (PL 175577); MA—microwave analyzer (PL 194256); DLGA—dynamic liquid and gas analyzer (P416515); TMCCB—transdermal meter for the concentration of chemicals in the blood (W110552); RSDSBG—resonant stimulating and diagnostic system of bone growth (PL 203731); UA—urine analyzer [19, 20].

skin thermoemission, without synchronization with the assessment of blood flow in microcirculation and electrical heart action, may be helpful when the assessment is made by an experienced physician who subconsciously takes into account synchronization patterns. However, in the situation of more and more frequent use of intelligent techniques (e.g., neural networks) and mathematical inference rules in order to generate diagnostic hypotheses by diagnostic support systems, the level of correlation of input determinants depends on the level of correlation of partial determinants and, as a consequence, the reliability of diagnosis. In the introduction, the thesis of the synchronicity of the processes of regulation of homeostasis of the body was put forward. The rapid increase in patient data forces the need for intelligent techniques of data segregation and processing (e.g., rough sets), as well as systems supporting diagnostic decision (expert systems). It should be added, however, that one of the key criteria affecting the quality of

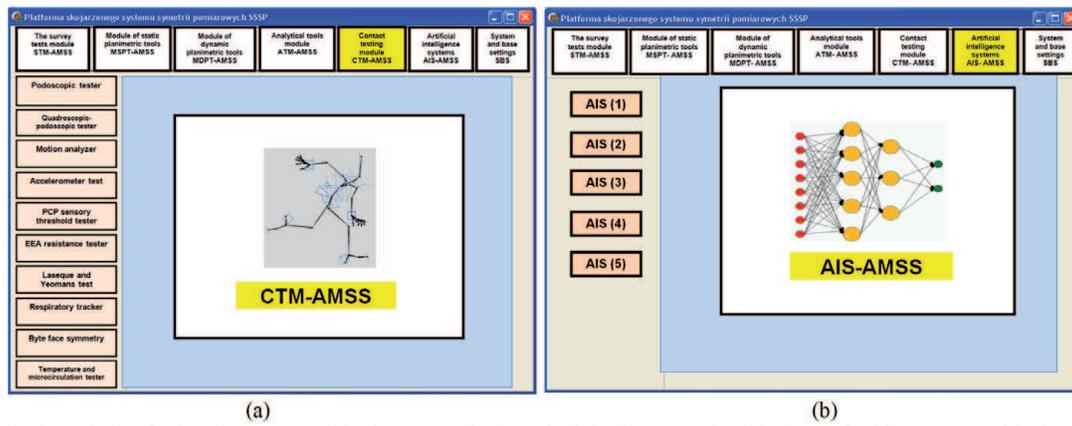


Figure 7.

The software platform SP-AMSS consists of (a) contact testing module (CTM) for the parametric evaluation of symmetry of parameters of temperature, photoplethysmography, parameters of resistance, impedance, reactance, and microcirculation blood flow, cooperating with the biometric interface and (b) artificial intelligence system (AIS).

the computer system is proper preparation of the input data. Therefore, there is a problem of creating a synchronous measurement and inference system, based on the experience of using the distributed measurement system, which allows the conversion of parameters and their presentation on a common time axis in order to outline interparametric correlations and assess their significance by applying system inference rules. One of the possible solutions to this problem is multipath measurement data acquisition, synchronized by a common time base. The network structure of the system can be easily adapted to the conditions in which patients are diagnosed in several offices, or a series of tests are carried out in different places. Each measurement module is able to attach a time stamp to the data record that is being sent, which makes it possible to determine many factors that depend on it, such as the need for repeated examination or the impact of rehabilitation on the patient's health. The time stamp is an important parameter that significantly affects not only the strength of connections between the test results carried out by individual modules but also the determination of the usefulness of the tests and their validity period. This in turn has a significant impact on economic planning and modification of procedures towards more effective solutions. One of the important elements affecting the results of the system is the proper preparation of the input data. For this purpose, elements of rough set theory will be used. Knowledge is understood here as the ability to classify objects of the studied reality, and its representation uses information systems of which special type is decision boards. One of the purposes of using rough sets is to generate a good, in a sense, universal set of decision rules—sentences of the form: “if trait and (1) = value (1) and (n) = value (n) is decision = value (d).” The creation of decision algorithms involves, among others, problems of knowledge reduction (searching for minimal sets of independent attributes, giving full classification of objects) and searching for dependencies between data. Detection of unnecessary attributes in the decision table will allow obtaining information on the basis of which, for example, you can change the attribute—increasing the time interval or rejecting the attribute. The use of appropriate classification algorithms will allow to reduce the number of objects or change the area of research, e.g., the location of the thermometer. The use of association discovery algorithms will allow, for example, to detect relationships between attributes and thus determine the degree of correlation between them. In the further part of the research program, this will also reveal the relationship between the effectiveness of treatment and the applied medical therapy [21].

2.5 Information structure in the system

The sectoral computerization of a single workplace or even a single healthcare facility becomes a controversial improvement due to the lack of compatibility, and, as a consequence, isolation in the area of information media flows to the traditional part of the system. This creates the need for duplication of media and procedures. A full-size hospital network integrating all workstations in one operating system, which is also used in other facilities, is the only way to effectively use the working time of sector operators and the fast, internal, and external flow of user and feedback information. An important factor determining the effectiveness and efficiency of the system is the central storage of information about operational entities (patients) and the correct solution of the issue of hierarchy of access to read and write data on the part of employees. Cross-department and cross-center patient information flow during consultations, laboratory tests, admission, and discharge should be based on a protocol of operational procedures unified at least at the national level. The first step in this direction, and also a minimal option, is to create an optimal parametric patient graph and an administrative reporting base, whose data, depending on the hierarchy of access (authorization code), can be obtained in the form of a file at any point of the network. The optimal variant assumes the introduction of an interactive archiving procedure, in which a multi-domain measurement file (parametric graph) is created under the patient's ID, which is gradually supplemented during the stay in subsequent diagnostic laboratories, consultation rooms, and hospital wards. The system's layout of file edit fields means that each diagnostic information is entered sporadically from the alphanumeric keyboard and most often applied in digital form, extending the electronically available level of knowledge about the patient's condition. Therefore, information about the patient takes the form of a sequence of parametric graphs on the time axis, which is particularly important when preparing discharge documents, which until now have taken the most time in the practice of a hospital doctor, since their creation required duplication of time using the keyboard in the procedure of manual rewriting of test results from paper medium. When the hospital network has access to the system layout of edit fields and parametric tables of the patient's information file, it automatically enters their content into the discharge document, which reduces the time spent by the doctor on administrative activities by at least 80% [22].

2.6 The role of unified criteria for metrological assessment of the musculoskeletal system

The system association of multidisciplinary packages of measurement files with patient's ID was important but only a first step in the creation of a modern, unified storage system. It should be noted that, this way, objective part of distributed information that so far has been stored on a paper medium was centered and accumulated on electronical medium in a form of numerical laboratory and electrophysiological parameters, which were referred to objective calibration patterns, source files of imaging tests, as well as numerous descriptive information (results of consultations with specialists, descriptions of imaging tests) that do not have its objective calibration pattern. The use of fairly diverse diagnostics in terms of, e.g., locomotor tests and tests of neurophysiological functions used in several wards, creates some communication problems in the field of communicating the assessment of patient's momentary state and even more of clinical results achieved with the use of different types of therapy. This is particularly important when moving a patient from ward to ward or leaving home with the intention of being re-admitted to further therapy at a later date. In the above situations, it is sometimes difficult to objectively determine the initial state and compare it after a period of stay at home or in another ward, and besides, the doctors of

subsequent wards are forced to duplicate many initial descriptive activities. In this situation, instrumental and thus quantitative determination of the topography of receptor disorders of the skin, muscle strength, thoracic respiratory path, vector indicators in the Romberg test, California gait indicators of the patient's gait, muscle electromyographic parameters, or nerve conduction, according to the hospital standard, gives the objective component of the state temporary patient, to whom the clinical comment of the doctor is attached. The file is available at any point in the computer network [23].

2.7 Hospital information system

The main goal of the hospital information system (HIS) [22] should be to improve the quality and streamline the patient's treatment process and reduce the operating costs of a hospital. The first SSIs implemented were based on large workstations (mainframes) with uniform software. Currently, the concept of architecture based on network structure and modular software, not necessarily from one supplier, prevails. The network structure, emerging databases, and connection with other hospitals and scientific institutions result in an increase in the quality of medical services provided. The use of computers with a properly designed information system contributes to the elimination of a significant part of errors and mistakes, completes and unifies the data, facilitates faster access to data, allows more efficient use of equipment, and shortens the patient's waiting time for admission to the appropriate department and effective treatment. The exchange of experiences (in particular those described parametrically) between medical personnel of various departments and environments allows for the development of standards in routine clinical management and in unusual situations. The reference structure of the hospital information system should include:

A system of **data presentation** enabling the standardization of patient data and, consequently, sorting, filtering, and classification (e.g., for the purposes of statistics and epidemiology). An important feature is data availability 24 h a day, 7 days a week from any terminal of the network. This postulated computer patient card should contain (in addition to a record of personal information) information about immunizations, allergies to medications, laboratory and imaging tests, opinions of specialists, a list of possible problems and complications, a plan of visits and consultations, issued medical leaves, information on surgeries, prescription medicines, and others. This list can of course be modified depending on the unit. The main elements are as follows: (1) **Knowledge**—a connection through the Internet with other centers. The introduction of the telemedicine techniques—video consultations, transmissions showing the course of innovative surgical procedures and access to the resource databases (MEDLINE), disease codes and procedures, and literature—facilitates the process of diagnosis and treatment. It is necessary here to implement appropriate mechanisms and tools for defining queries and search the available resources. (2) **Communication**—cheap, quick, and easy medium for the physicians to communicate with each other or with patients. Great opportunities are given by the e-mail: e-mail, group mailing lists, SMS technology in mobile phones, videoconferencing, and video consultations. (3) **Alarms, reminders, and suggestions**—automatically generated messages when selected parameters of patient care do not meet the standards. It is a kind of a quality control system, difficult to achieve with other methods. The final decision to take a given action rests entirely with a licensed physician.

2.8 The network structure

At the moment, only systems using Web technologies are being considered [22] as the best solution from an economic and ergonomic point of view, also taking into

account the rapid development of the Internet and of related, so-called e-services. Already well mastered LAN and WAN technologies may be used for this purpose. Implemented software must be running in terminal emulation mode or in application mode client–server. A correct and strict control of access to the information is indispensable—mechanisms for logging into the system, password protection, supervised connections (scripting), as well as coding and encryption procedure of data meant to be transmitted. It is important due to the Personal Data Protection Act—L.G. No. 133, item. 833 of 1997. It is also important to ensure compatibility with various hardware platforms and operating systems (Windows 9x, Windows NT, Macintosh, UNIX). Thus, we need to provide multiple ways of presentation that provide for the most popular types of terminals: IBM3270, VT100, MS Windows, X-Windows. Another essential element in the architecture of the proposed information system must be taking into account various network protocols for the transmission and exchange of data, TCP/IP, IPX/SPX, and HL-7, as well as implementing special dictionary translator interface, responsible for the correct interpretation of information passing between the applications of the system. A conversion of data and codes of different applications is usually needed to create a common representation. Usually, such conversion is carried out “on the fly,” using appropriate interfaces. To conclude, we also need to take care of a friendly and easy-to-use user interface.

2.9 The elements of artificial intelligence

Information theory (by Shannon) [22] refers to a sequence of events, to the occurrence of which a certain probability can be attributed. Such an approach means that both the amount of information that implies an event and the total amount of information in a particular series of events can be specified. Information is, therefore, the opposite of probability. Repeating information in the transmission (redundancy) reduces the transmission efficiency of the communication system (doubling the sequence) but increases immunity for disruptions in the information canal (loss compensation).

The decision support system is an organized set of experts, procedures, and technical equipment used to support the effectiveness of the decision-making process. Its task is to improve the quality and efficiency of the decision-making process by simultaneous access to knowledge with a structured access path, as well as to the data with no such structure. Thus, the decision support system is a way to make two kinds of system resources available to the user: the source data bank and the bank of operational data processing methods. The computer decision support system is not able to replace human in any part of his activity; thus, it functions as (1) an instrument supporting the memory and tool-making capabilities of the decision-maker; (2) an incentive (or even a push factor) for precision and consistency in formulating research questions, method of demanding, and searching for the scope and criteria for making optimization; and (3) a facilitator for groups of decision-makers (in particular) operating at lower levels of the management structure, allowing to make informed decisions without the need to have confidential knowledge about the whole system. The development of decision support systems is carried out in the following directions: (1) interdisciplinary modernization of system methods by employing specialists not only in narrow specialties but above all in theory of decision-making, management, operation research, cognitive psychology, fuzzy logic, and mathematical modeling; (2) the broadly defined typing of information technology, the development of which moves toward electronic data collection and conversion of existing archives; and (3) development of technology and methods of communication with the electronic archives. Features of the decision support systems (DSS) include (1) presenting information in the form that is known to a

group of users, (2) selectivity of the information provided, (3) supporting and not replacing the decision-making process of the decision-maker, (4) supporting the structuring of the decision-making process, (5) flexibility and quick response to the user needs, (6) supporting various styles of decision-making, (7) acting in different phases of the decision-making process, and (8) cross-checking of various phases of intertwining decision-making processes realized according to different styles.

An expert system is a technically implemented or software-independent algorithm modeled on the activity of the nervous system that can, on the basis of provided or measurement data, make decisions regarding regulation of the control object in a specified range of prediction. It is the use of computer that solves complex problems requiring expert knowledge. To achieve this objective, the expert system simulates the process of human reasoning, using specific scientific knowledge of nature expressed with mathematical inference rules. An expert system (according to Feigenbaum) is “an intelligent computer program that uses inference procedures for solving problems, which are difficult enough to require significant expertise of the specialists. Knowledge, together with the rules of inference, can be regarded as a model of expertise normally achievable only by top professionals.” The following types of DSS are distinguished: (1) **Specialist**—bespoke for specific users, regarding their specific problems and ways of solving them. (2) **System generators**—programs allowing for construction of specialized SWD, quickly and easily, based on the system core, often with no need to consult with industry authorities. (3) **Tools**—software supporting other systems, often added as modules or separate programs (graphics system, database type and method of access, software packages, etc.). Within DSS, there are categories that can be distinguished: (1) **Consulting systems**—presenting solutions to the user that can assess their quality. They are usually collected in order of increasing probability. (2) **Systems making decisions without human control**—they are used for the control of dangerous or microautomatic systems (e.g., insulin pumps). (3) **Criticizing systems**—they verify the problem presented to them in the form of a graph, equation, or diagram, showing a list of discrepancies (with known rules) and a list of suggested corrections. The result of an expert system may be the following: (1) **Diagnosis**—assessment of the current state of the object, based on the data processed on the basis of the installed inference rules. (2) **Prognosis**—prediction of future states of the data processed on the basis of the installed inference rules. (3) **Plan**—a sequential-structural description of the state to which the system aims at in a given operating cycle.

Expert systems (ES) are an evolutionarily younger product of the development of knowledge engineering, often based on the existing knowledge support systems. Both systems operate with the use of (1) artificial intelligence, (2) design methods, and (3) functional fusion of systems. The backbone of artificial intelligence can be used to build both DSS and ES. The main directions of the application are (1) model knowledge bases in the range representation codes especially for specific disease entities, access paths, generators of convergent, and alternative and contradictory definitions and (2) construction of sophisticated models of the simplest access and data presentation interfaces, with a tendency to engage in dialog in natural language (according to the principle of “the advanced background technology”) [23].

In the large system of spatial regulation of the whole organism, there is a hierarchical-parallel organization of the interdependence of individual centers and circuits. It consists in the fact that the regulatory influence of parent structures on a number of processes at the lowest level is limited in the possibilities of changing local parameters only to the optimal values, which fall within the range of autonomous function of the subsystems. Principles of intersystemic cooperation shaped this way cause, that in moments of special mobilization of the entire body, it is not at the expense one organ or group of cells only, but each of the systems contributes

to homeostasis with its “regulatory surplus” that exists around its optimum of functioning. The disease process is based on local or generalized overrun beyond this principle. Creating models simulating the functions of living organisms should not be mere mind gymnastics or a test of skills in practical application of the possibilities of mathematics, electronics, and software, but a practical and functional facility solving specific problems in various fields of science. It is necessary to realize that in modern science, there is a number of excellent diagnostic methods used at the most basic level, without mathematical apparatus that guarantees high specificity and accuracy. A key task for an IT specialist in biology and medicine is the use of digital machines for the processing and description of signals or images of biological objects. Combining the power of the mathematical apparatus with an instant access to data library containing expert knowledge, a significant deepening of the level of problem understanding is obtained, even at the stage of preliminary data analysis. In this new situation, a doctor or biologist will have knowledge, normally reserved for highly specialized centers, and the practical consequences of this fact should not be long to wait for.

However, in order to use digital computational technique in humans or other living organisms, there is a need to “translate” the axial physiological functions of the body, both in the state of health and sickness, into the strict language of structural algorithms that can be identified with the “disease models,” compiled then with higher-order language to the level of digital functions. The most valuable feature of the artificial neural networks is their ability to process information in a parallel way, as well as the learning process, that replaces traditional programming. The operation program of the network is included in the topology of connections and their parameters, that is to say weights. Solutions to the tasks the network should solve are presented by means of the output signals. The most important problem during the construction of an artificial neural network is the selection of the network architecture to a particular problem. The choice of a neuron model and the method of teaching the network are also important. The best solution for the classification tasks is one-way network, while, for example, for complex optimization structures, a feedback network. Learning is a process that leads to consolidation of specific behaviors, based on experience. From the technical point of view, the problem boils down to determining the product of the scalar signal vector and the instantaneous weight vector of a discrete network element that can operate in a time or space pattern. In the artificial neural networks, learning is a process where each stage is usually visible as a cause-effect relationship. Teaching the network means forcing specific response to the input signals given. In artificial neural network applications, supervised learning and indirect supervision learning can be distinguished. Teacher-assisted training of the network requires preparing an appropriate set of input and output data, i.e., the training set. During learning, each cycle checks whether the network response is as expected—if not, then the weight change process takes place. Teaching lasts until all responses to the learning set data are correct. They are considered to be such, when the difference between the output of the network and the expected signal is less than the established maximum error.

2.10 Clinical implementations of AMSS system elements

I introduced lateral coefficient methodology in medical diagnostics in 2000, initially to the description of the Lasegue test [24], later to assess goniometric techniques, X-ray planimetry, and podoscope planimetry [25]. At the turn of 2003–2005, the idea of the lateralization indicators developed in the direction of multipath symmetries [15]. Since that time, the idea of multipath symmetries was successfully tested clinically on medium groups of patients [26, 27] and large groups

of patients [6]. A very important consequence of this completely new approach to the diagnosis was making an important discovery and acquiring clinical evidence that together with asymmetric scheme of long-term physical adaptation of the organism in the course of pain syndromes, bone remodeling occurs in the twin supporting elements of the bone structure, which can be described using lateralization indicators [28].

A summary of the above idea was presented in 2010, in Łódź, at the 7th International Congress of the Polish Rehabilitation Society, in the form of paper entitled “A system of associated measurement symmetries as an EBM tool in standardizing the diagnosis and surveillance of the musculoskeletal system treatment,” and then awarded by the Scientific Committee of the Congress. This paper contains the idea and the general modular design of associated measurement symmetry system (AMSS). This issue is discussed in more detail in two chapters of the post-conference monograph [29–31]. Techniques of describing patient’s clinical condition (taken from the SSSP system) were also used in a large clinical study, published as a book chapter in the United States [1].

2.11 The role of the AMSS system in anthropometry

The primary goal of the AMSS system, especially in the context of anthropometry, is to present vector biomechanics parameters as part of a time-oriented parametric graph. It is worth recalling and emphasizing that the parametric graph contains the following:

1. Subject’s emotional profile, determined using survey tests (intelligence-abilities-depression) and planimetric silhouette tests (parents, family house, tree) (TA-AMSS), approximating more important features of the emotional state, which may affect the qualitative dimension of intentional movement creation.
2. A biochemical profile of the subject (MNA-AMSS), which could have a modifying influence on the qualitative selection of intentional engram of movement creation (e.g., thyroid or adrenal gland dysfunction), the functioning of the neural network in which the engram will operate, the functioning of the motor neurons and pyramidal tract, the functioning of the neuromuscular feedback (motor plates), and the functioning of the muscles.
3. A profile of the subject’s static structural symmetry, determined by the module of planimetric static tests PTS-AMSS, which contains a set of utility programs for automatic planimetric measurements in static radiological, scintigraphic, ultrasound, and thermographic images (mainly symmetry, distances, and angles). The application of these easy-to-use planimetric tools gives the ability to create numerical symmetry equivalents for specific pairs of markers on the images of the subject’s body structures. To improve the system’s functionality, measurements should be performed on a standard matrix of symmetry markers, enabling the acquisition of specific lateralization indicators and above all free, inter-center exchange of information while creating a knowledge capital about the patient, with no unnecessary duplication of procedures in subsequent centers.
4. A telemetric profile of the dynamic, contour-structural symmetry of the subject, determined by the module of dynamic planimetric tests (PTD-AMSS), containing devices for telemetry measuring the symmetry of body movements and its anomalies, in particular enabling parametric evaluation of drift-related

asymmetry indicators, recorded as the sum of parallel, parametric asymmetric strings, marked with a time marker.

5. A contact profile of the subject's dynamic symmetry, determined using the module of biometric tests (MTB-AMSS), equipped with measuring devices having direct contact with the patient's tissues (e.g., tensometry, plethysmography, pulse oximetry, EEG, ECG, EMG, magnetometry, resistometry and resistive tomography, accelerometry, gyroscopy, assessment of the impulse perception threshold). It collects information about the functional symmetry of motion (muscle) effectors, the functional symmetry of peripheral effector control (nerves), and the functional symmetry of effector supply (blood vessels).
6. A system of time stamps.

The multitude of parameters obtained from the AMSS system will, in the first phase, hinder the orientation, even for an experienced doctor who is not a specialist in anthropometrics and psychometrics. This problem can be solved by the module of artificial intelligence system SSI-AMSS which (depending on the needs) allows for the use of advanced intelligent tools to perform (a) the erosion of the information stream without the loss of significant content, (b) thematic organization of information, (c) diagnostic inference based on decision support systems (generators of hypotheses), and (d) inference based on expert systems and (e) determine the numerical size of disease progression and remission trends (resulting from the treatment). A large amount of collected data is related to the problem of its efficient processing, aimed at obtaining cross-sectional knowledge about the patient. In medical diagnosis supported with computer methods of data analysis, making the right decision is crucial as it determines the time of making diagnosis and treatment initiation and, consequently, patient's life and the costs of treatment.

2.12 Further development plans for the AMSS system

Further work (modeling on the ECG cardiological standards) will aim at the medical community's interest in creating a friendly and comprehensive numerical standard of musculoskeletal system symmetry (SMSS), determining symmetry coefficients (or asymmetries) according to topographic patterns of the osteoarticular, muscular, nervous, and circulatory systems [32]. The purpose of implementing the new system is to provide a new, more universal tool that can be used to create a protocol for inter-center exchange of information. The program plan includes the following:

1. Improvement, unification, and typization of the marker matrix (MM), a system for electronic registering of data and software.
2. Development of the diagnostic screening package (DSP), which is a set of optimal topographic and parametric patterns (TPP) characterizing the state of the organism.
3. Establishing a set of physiological patterns (PP) that characterize the normal state of the body and will function in the information database as a frame of reference. This data will be collected after applying the diagnostic screening package (DSP) in studies on subsequent large age groups of healthy individuals, thus reflecting a natural phenomenon of parametric involution.

4. Optimization of the qualitative selection of the topographic and parametric patterns (TPP) in specific disease units, in order to be able to repeatably present them as indicators of symmetry (or asymmetry) on the quotient scale.
5. Beginning to work on the base of pathology patterns (WP), through the use of the diagnostic screening package (DSP) in studies on selected groups of patients for whom the selection process was carried out on the basis of highly specific diagnostic criteria.
6. Multi-center clinical tests, leading to the parametric unification of physiological (PP) and pathology patterns (WP).
7. Reconstruction of electronic devices, software, and clinical criteria—based on feedback.
8. Multi-center unification and typification of the system and procedures.

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