# *From body to map & back. Drawing body maps: on skin, on paper, on bit and on neurons. A core for recently established anthropokinetics*

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**Abstract.** Man creates maps of land, of earth, of sky, of real or imaginary worlds, of micro- and macro-cosmos, of everything, including his own body. Maps are useful for knowledge and for practice, linking one another these two kind of relation with the mapped space. When we say "body maps" we can mean both "maps of body" (representing body) and "maps on body" (representing something else that is projected on body, even forced to be adapted for coinciding with body). Maps are not simply a double of a country or of a body. Mapping gives a different and further ontology to the represented objects by a cause-effect circle, by a dialectic relation between two extended territories (the concrete one and the mapped one). Human body has been mapped as a land to orient our own or other's navigation. To do this we need marks, references, directional systems: polarities, oriented lines, preferential protocols. Marks may be based on existing anatomical features or on projection of conceptual/symbolic elements, transcending somatic concreteness, relatively heterogeneous to flesh. The anatomical features can regard soft or hard tissues, similarly to "*complexio*" and "*constitutio*" of ancient physiognomy. This navigation is aimed to find signs, to read text(s) that is/are written on its surfaces and in its deepness, to act on it. The body maps taxonomy can be based on supports: skin, paper or bit or to contexts/purposes: official medicine (that presents iconographic maps as 4D body imaging and not iconographic maps as DNA), alternative medicine, figurative arts, physiognomics, mantics, motion capture in cinema, erotic contexts (the ancient *ars erotica* and the modern *scientia sexualis*) mystic cosmology and so on. A particular case of neuronal mapping is related to movements. This perspective leads us toward a precise direction, grounding the study of the human movement in a very interesting way. This study is still looking for its own center that can define its specificity, its epistemic identity. The term "anthropokinetcs" (from the Greek words *anthropos* and *kinesis*) seems to be fully capable of indicating this recently established (in Anglophonic world, but still not existing in Italy) disciplinary area. This term is obviously related to "anthroposomatics", that indicates the field of the studies related to human body. We aim neither to erase the legitimacy of existing studies of many different sciences that are referred to moving human body nor to create a double of these studies. Instead, we would like to offer them an organic frame to organize their contents and their methods, in order to apply and to communicate them in the best way. This line of study has the purpose of understanding human action thanks to researches that are capable of integrating biomechanical approach with neuronal one (definable "neuro-mechanics"). First of all this approach originates a dialectic play between these two areas (but many others must be involved, as robotics, semiotics, EEC, IIB) and shows that the Nervous System is a "black box" that, after motor learning, manages sensory-motor information as space-time derivatives and integrals. So the CNS is competent (it owns the necessary acquaintance) as an engineer, even if according to a different formalization, it is based on neuronal sources. Anyway it solves real time and with efficacy the interaction problems, managed as input-output patterns. Here we propose to follow and to empower the recent establishment of the anthropokinetics, a knowledge of human action that can be applied in many fields: ergonomics, therapy, motor techniques (in work, in sport, etc.), didactics and so on. Engineering can offer adequate and effective models for the study of the execution of human action. The connecting rod-crank mechanism and, generally, the mathematical-physical approach to moving bodies are meaningful examples. Writing the "*trait-d'union*" to link one another the biomechanical and the neuronal data means reaching the heart of the matter. When we speak about neural functionality we have to interpret this as the biological datum correlated with the abstract thinking and cultural elements. The natural location of this researches could be seen in the motor sciences academic departments.

*Those who see any difference between soul and body have neither*
(Oscar Wilde)

## MAPPING BODY...

Man creates maps of land, of earth, of sky, of real or imaginary worlds, of micro- and macro-cosmos, of everything, including his own body.

He uses many different matters to draw these maps. The first and meaningful one is the skin, so the map is on the body and the denomination "body map" means that the body itself is a map. When the map is separated from the body the most used support has been and is still now a writable surface, that is paper or a similar one. Since the late XX century, the digital tech-

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nology has allowed us to realize virtual maps, whose implication in creating, managing, reading, using are deeply different. These epochal transformations has produced feedbacks on the previous way of formalizing maps, changing many of their aspects.

So when we say "body maps" we can mean both "maps of body" (representing body) and "maps on body" (representing something else that is projected on body, even forced to be adapted for coinciding with body). Sometime these can coincide: on skin we can draw the map of the interior organs.

Body iconography is very diffused in many cultures since a very long time.

The western culture has always created many models for body representations, and not all are maps.

The representations have different features, they satisfy many different aims: searching of beauty, of perfection, expressing or formalizing aesthetic tastes (art), building of texts of knowledge (scientific illustrations), showing the invisible, offering an object, following devotional practices (sacred iconography). Disregarding features and functions, these representations have always created a double of the directly perceived body. This double is a mirror (to compare, to recognize our body) and a filter, through which one can watch his own body, both a limit and a source to interpret and to value real body.

Body would not be the same (in the living experience as much as in the culture) without the representations: the flesh is not the only matter that composes body. Paper, pencil signs, colors, marble, pixels and so on (in iconography, but also words and other semiotic devices) are part of our body.

There is a long history of parallel courses of artistic and scientific illustration, with many reciprocal crossings (Leonardo and the Renaissance) or analogies (anatomical iconography has been inspired to artistic – pictorial or engraving – models during many centuries, since renaissance until the eighteenth century, after, on the contrary, art will be inspired to scientific knowledge and models). New technologies (photography, cinema and, later, digital devices) are a decisive turning point that reconfigures a new relation between art and technology, where the second one becomes independent and offers original models to art. Beginning from impressionism and so on with futurism, we can see as that the art passes across the filter of technology.

From the irenic contemplation requested by classical art, to the devoted faithful sight of the believing of Medieval Age, from the spatially placed and geometrically valuing eye of Renaissance spectator of art and architecture, from the calculating view offered by technological drawings and engineering projects to eye-lens of Vertov, our organic device to watch has been involved in many different ways and with different grades.

Virtual avatars are replacing first person body: its centre becomes double and our sensory-motor functions are projected out of our boundaries.

Human body has been mapped as a land to orienteering our own or other's navigation. To do this we need marks, references, directional systems: polarities, oriented lines, preferential protocols.

Marks may be based on existing anatomical features or on projection of conceptual/symbolic elements, transcending somatic concreteness, relatively heterogeneous to flesh. The anatomical features can regard soft or hard tissues, similarly to "complexio" and "constitutio" of ancient physiognomy.

This navigation is aimed to find signs, to read text(s) that is/are written on its surfaces and in its deepness, to act on it.

Thanks to maps, body is no more an unknown, obscure landscape: a map that is projected onto body, overwritten on body, is a source that allows to cross and to solve the limit of mystery, of chaos.

Observer's eye cannot get lost. It needs rules and models if someone wants to understand body and to act on it.

Mantic arts, physiognomic typing, cosmic vision of Renaissance, artistic canons, medical diagnosis find in maps decisive reading keys.

This paper wants to show a comparative vision of these arguments that may be seen in a historical perspective too. So it allows to see similarities, differences, relations, derivations, drifts, statistic frequencies of beliefs, behaviours and so on.

Maps can be:

i) implicit (unvoiced) as the maps of decency, of showing off parts (for erotic appeal, for displaying muscles as a peacock, etc.), of touching/ touched parts;
ii) explicit: iconographic or verbal texts represent body.

Applied technologies contribute to establish and to build new models of body imaging aimed at drawing maps and new ways of interacting. Digital elaboration and synthesis of body imaging allows a quality/quantity extension of perceptive fields, makes visible the invisible.

Due to body maps, disregarding their particular features, the existential perception of real body passes through these models that are absorbed during enculturation processes.

Body is not directly examined and valued (see diagnosis in medical contexts) as concrete living flesh, but basing oneself on the (technological or not) maps. The distance between the observer and the body (even if they coincide) becomes larger and larger: the interposition of map is unavoidable and map becomes "part" of body.

Anthropometric measures and anatomical taxonomies are analytically placed on body maps.

Living body is the field where we can recognize map's contents and it is recognized thanks to maps. Real body is the screen on which maps are projected.

The biological projection can be found in our body, determining articulated maps: dermatomes and *ho-*

*munculs motorius* or *homunculus sensitivus* are the most famous example.

Anyway maps aren't simply a double of a country or of a body. This is to say that maps aren't simply the neutral representation of the reality (bodily or not). Mapping gives a different and further ontology to it. This operation creates a double sense process that allows us to attribute meanings and sense to reality. To be more exact there is a crossing attribution of meaning and sense between land (in the most general sense: if it is mapped, the body itself is a land…) and map. Abstract meanings, according to cultural paradigms, to tastes, to believing, to (supposed) relations with world etc. cannot be attributed directly to body. The intermediation of a map is necessary. In the meantime the experience, the perception of the body and of the bodies are the source and the reference to build the map.

This creates circle of cause-effect, a dialectic relation between two extended territories (concrete one and mapped one), a "point-to point" correspondence.

Mapping is created and used as an approach, a criterion to relate oneself to a territory, an instrument to explore and to read, to know, to own it.

Map is an instrument to make the territory or the body something different. Mapped land or mapped body is different from land or body of the only direct experience. Mapping creates a hiatus, a distance from the self, a space that allows cognitive and cultural processes. It allows the objectivities that we give to external world. This relation has effects that come back to the self, so the experience is not erased but is no more the same. It is not a chance that someone speaks about "bodyscape": a term that is equivalent to landscape, used about territories.

Skin is the first place for mapping body: it is the boundary on which world and body meet one another. It belongs both to body, it is its surface, there is continuity between it and the underlying flesh or organs. But skin is viewable by external watchers, that can explore it to find places, points and references related to body's deepness, to accede the internal invisible organs.

The subject can explore himself, too, even in a different way and according to a different perspective.

Finding exact points by visual and/or touching exploration is (more or less) the same as reaching the related organs.

Skin is a map composed by a rich and complex set of "topoi" and with its own naming system. The network of this points reveals a typical pattern or structure. This network is obviously functional to the purposes of the map (diagnosis in medicine, motion capture, mantic arts and so on)

There are many different contexts and many different criteria to draw a cartography of the body.

We can try to articulate a taxonomy of the body maps that is based on the supports. So we can individuate three fundamental typologies: maps on skin (body's surface), maps on paper (material support where we represent the body by opportune icons), digitalized maps (structuring information by the digital code). The last ones are the most plastic ones.

Another taxonomy can be based on the criterion of correlation map-body and on the purpose of the mapping. We can individuate many meaningful examples.

## MAPPING BODY IN DIFFERENT FIELDS

### *Medicine*

Body cartography has a central role in medicine. Anatomy is basic to medicine. It is visual and its texts are mainly iconographic. The starting point of this principle can be referred to a vesalian sentence "To see is to know", still visible in the anatomical hall of Uppsala, in Finland. This can be otherwise confirmed by further examples: Comenius, the proportional compass, that in 1568 was requested by the anatomist Bartolomeo Eustachi to the mathematician Federico Commandino. The compass is an instrument that usually is typical of reflexive geometry or of geographical cartography. The Eustaki's request demonstrates that limits among disciplines are going to be crossed. The recently established scientific anatomy takes advantage from these contaminations.

The principle of primary importance of iconography, in the age of 4D atlantes, gains a different and deeper meaning. Imagines have an extraordinary communicative efficacy and own a much bigger effectiveness in comparison with words in interpreting concepts related to our body morphology. The iconography is not a complement, a support to the verbal description, but they constitute the center of the watching, analysis and learning system.

A first type of body cartography is based on landmarks, properly reference elements on our body. We can distinguish two fundamental types of these points:

- Skin landmarks;
- Bone or skeleton landmarks, that can be individuated by palpation of particular body eminences trough surface tissues.

The last ones are preferable because the position of skin landmarks changes even in a same subject, according to body mass index.

Anatomy, both topographic or regional, starts from description of body as divided in four main parts: head, trunk, superior limbs and inferior limbs. This summary division can be considered as a similar version of the Aristotelian taxonomy (the trunk is considered the center and it has five appendixes: the head and four limbs). The limit between a region of these and the next one is defined by lines that are drawn basing them on skeletal points or on anatomical elements well evident on body surface.

In each part we can individuate further regions owning their exact anatomical identity (for ex. thorax, abdomen, pelvis, neck, etc.).

This kind of cartography offers an important base to

semiotics and surgery, due to furnishing to physicians the location of an organ and allows to value the ways of access in surgery with speediness and sureness.

Another kind of cartography is based on dermatomes, that is to say skin regions innervated by a unique spinal radix.

Each posterior radix of a spinal nerve furnishes sensitive fibers to a certain skin region that is called dermatome.

Analogously, every anterior radix of the same nerve distributes its motor fibers to a corresponding muscular district, called miotome.

The dermatomes on neck and on trunk have a regular shape, as ring stripes originating from medial-dorsal line and go roundly till medial-ventral line, almost perpendicularly to vertical body axe.

On neck however skin regions become less exact and they have a prevalently trapezoidal shape. On limbs dermatomes have a more complex shape and a more various extension.

This complex cartography shows a perfectly symmetrical disposition.

If we climb from spinal nerves (sensitive and motor) to brain's cortex, we can find a different mapping, respectively relatable to the "*homunculus sensitivus*" and to "*homunculus motorius*". Cortex and body are each the projection of the other.

This can be considered a properly double sense biological map.

However an informational biologic system as the brain needs a projective correlate of the controlled system, with a warranted correspondence point-to-point.

The correspondence surface-deepness is not only regarding exploring, perceiving and knowing, but also acting on internal parts. Pressure, warmness and other physic actions can be transmitted according to a contrary direction, centripetal instead of centrifugal. This direct projection is used by common sense and by medicine and physiotherapy.

In ancient and exotic conceptions internal/external correspondences are directed in different senses: a part of the body can be considered the projection of a bigger one. The whole body, for example, in auriculotherapy is projected in fetal position on the external ear, in podology is projected on the lower side of the foot.

A very important body map of 20$^{th}$ century is the map of DNA. It is not an iconographic map: it is coded by a simple set of four elements. Besides it is a linear, monodimensional code. This poorness pushed scholars to believe they were not able to code the very complex three(four)-dimensional composition of the organism. So they undervalued the coding sources of the "ACGT alphabet".

The genome doesn't code only organism's feature (the 3% of DNA is enough to specify all phenotype's structure. Mainly part of DNA is aimed to further functions: control, overview, differentiations and so on. In order to obtain this the genome should interact with genetic and non-genetic factors. The whole organism is coded by the genome. The same genome is present in each cell, but it expresses differently according to the exact typology and place of the cell.

The evolutionary and developmental processes structure this double-sense map:

- Organization of somatic micro- and macro-architecture, tissue type of the cell, relationship with other cells, shape, dimension and structure of organs, systems and apparatuses is decided by DNA. In other words the map of the body is written in DNA-text. Here there is the drawing of the body, it allows and leads processes of building the body according to preexisting information.
- The localization of the cells, external influences and other factors lead the expression of DNA in different direction: epigenetic processes have been recently reconsidered as fundamental elements in development and even in evolution. Concrete body history draws DNA's map. The location of the cell or the accidents happening during its life become information as much DNA's sequence.

Another not iconographic map is the EEG: each trace is related to a particular region of the brain and represents its electric activity.

Medicine (instrumental diagnostics, body imaging). Besides the nomothetic mapping that illustrates The Human Body, there are other methods to map a human body, the body of a sigle specific person, with a diagnostic/therapeutic purpose. Modern technologies allow the realization of images of body using several physical properties of the body itself. From thermography to scintigraphy, from x-ray to ultrasound scan. Other mappings are not as much iconographic and they show in a not analogical way physiological parameters related with localization, such as EEG.

In plantoscopy we can obtain instrumentally maps in which it is possible to observe, for example, the pressure applied by the soles in the foothold or by other parts of the body. This allows us to value in a combined way the morphology of the interested part and the load distribution, in the single instant or in time (for example in the performance of a pace in ambulation).

4D digital anatomical atlases. We build a dynamic image with general and nomothetic value. The represented body is virtual, but the image is concrete, manageable, usable and even open to further personal implementations. 4D atlases are an extraordinary tool for the anatomical knowledge of body.

*Alternative medicine*

Acupuncture. Assuming the existence of connection ways between different parts of body, we draw on the body surface meridians and various reference points capable of locating the right places where the needles should be threaded in order to obtain the desired effects. There are several maps with different origin and configuration. The psychosomatic maps are an example. There

is a wide range of this kind of maps, whose aim is to give a physical, energetic and psychosomatic picture of the human being. Among these different types we can indicate the two main ancient maps: the Taoist and the Tantric-Yogic maps, which are among the most complicated and careful. In addition there are two important modern maps: the neuropsychic map and the Reichian map. We can see several tries of creating a new version capable of integrating them one another.

Reflexology. Assuming (apart from the scientific validity) the existence of projective connections of the whole body with one of its parts, we believe that it is possible to act indirectly on every structure of the body acting on the corresponding peripheral region. This conception entails a one-to-one correspondence (from the whole body to its projection – hand, foot, auricle, etc. - and from the projection to the whole body). Reflexology uses this kind of map as a diagnostic and therapeutic instrument.

The Vega test, also known as electrodermal test, has been developed by the German Reinhold Voll in 1958 and it measures the electromagnetic conductivity of the body through a galvanometer. The patient who undergoes the test holds an electrode, while the operator locates a second electrode on a specific point of the patient's hand. The specific point is identified following some criteria that are similar to those ones used by acupuncture. There is a real map of the palm in which every skin region corresponds to an organ. At the same time in a particular structure of the machine the operator locates the allergens.

*Motion capture*

Digital technologies allow in cinematography to transfer the motion (both the macro-motion and the micro-motion of the face of a real person) to a synthetic character. This process is realized determining in both the figures, the real one and the synthetic one, a constellation of points considered significant by the motion capture technicians for their purpose, that consists in making the digital figure do the same movements and assume the same expressions of the real actor. The virtual figure becomes a sort of avatar whose movements are similar in 4D to those ones of the concrete actor. The location of some points is chosen following an anatomical-functional criterion, such as the joints of the limbs; others are chosen for their importance in expressiveness, such as some points of the face.

There are many ways for mapping face or whole body. The reference lines or areas can be projected on model starting from a virtual screen whose geometry is different: plane, cylindrical or spherical.

So we have:

Uvp: Planar mapping. The projection is from a flat opportunely oriented surface.

Uvc: Cylindrical mapping. The projection is from a cylinder that wraps the model. Diameter and orientation of the cylinder must be chose according to model features.

Uvs: Spherical mapping. The wrapping spherical screen is positioned to contain the model.

No one of these methods is better: if we map the whole body, instead of the only head, these three methods have to work together. Each of them might work for some areas of the body, but not others. Only composing the three methods we gain the best result.

Each of these methods will cause evident stretching of the projected reticule, distorting the modular pattern. This is more evident around the poles (top and bottom) and requests changes of projecting method to get the best coverage for that particular body part.

*Biometric parameters*

Biometric parameters are somatic features that are chosen as capable of identifying a person reducing to about zero the possibility of a false positive or of a false negative. The feature usually used to this purpose are iris, face morphology, digital fingerprints and voice. The recorded feature is elaborated to be transformed in a map. This map is memorized, classified and compared by digital methods. In order to decide the identity of the subject the comparison can be made one-to-one (to discover if two person coincide or not), or one-to-many (to discover the identity of a person if belonging to one of a data base). The effectiveness of these maps is based on individuating opportune key points. The configuration of their network presents meaningful patterns that allow to eliminate most of the risk of error.

*Mantics*

In mantic arts, aimed at knowing the future, there is a very scrupulous attention to somatic particulars, according to exact maps.

Body maps of mantics are often very detailed. Hand, iris, or other external parts are read to know the future of the subject owner of that part. The reading of an internal part, more frequently of an animal, that was ritually killed for this purpose, was aimed at knowing the future development of an important event, as a war or similar.

Many more or less ancient examples of these practices may be cited.

*Cosmic symbology*

The cosmic symbology (as physiomantics or physiognomics) in mapped body has very ancient origins. It has important developments in Middle Age and Renaissance. During these periods body gains cosmic references and becomes a projection of the terrestrial and sidereal world. Stars, constellations, the zodiac, the four elements (air, water, earth, fire), and also vegetation, volcanism and many meteorological and geological phenomena have been considered corresponding to different parts of the body.

Just in the Renaissance the direct observation of cranial nerves, twelve pairs, seemed referable to the twelve zodiacal constellations. Also the microscopic world finds its correspondences to body, that becomes

the proportional medium between micro- and macrocosmos. Body is the crossing point that gives continuity to so different dimensional scales. Micro and macro are linked in body and by body. For this reason body is named "*copula mundi*".

*Religion*

In different organs and in the whole body Biblic tradition and Hebraic mysticism individuate meanings that link them to divine and to sacral sphere. Due to this body becomes a "flesh book", a further text that speaks about divine arguments, about present, past and future, about health and disease and so on. The main feature of Christ's body is the fact that it is wounded according to a particular map: the four extremities and the centre. These five points draw a cross and they are "transmitted" to holy men and women by a miraculous projection. This constitutes the maximum of similarity between Man and God.

*Ars erotica - Scientia sexualis*

The *ars erotica* of classical world looked for and illustrated the way of the pleasure of the senses, it guided in the experience of sex, an experience in which the body was protagonist and subject. With the coming of the Modern Age we can observe a reversal of the position and of the role of the body from subject to object: the *scientia sexualis* examines, names, explains in more and more medical terms the sexual activity as a physiological function. This process goes on until, in the passage from the 19th to the 20th century, with the psychoanalysis, its roots dig in deepness, under the conscience and out of will. The libido arises humoring (at most it is bridled a little by inhibition) the dynamics of the instincts, the incoercible forces that link us with natural and animal world. Both *ars erotica* and *scientia sexualis*, and the psychoanalysis too, draw their own maps, following their own criteria and giving meanings and roles to the different parts of body.

Then we should consider the eros of other civilizations. If we consider the indian civilization and in particular the Kamasutra, we can observe that the parts of the body that should be kissed "conventionally" by the lovers are the forehead, the hair, the cheeks, the eyes, the chest, the breasts, the lips, and the inner part of the mouth. Something different from the map of the erogenous zones of western culture…

## "NEURO-MECHANICS": A CORE FOR RECENTLY ESTABLISHED ANTHROPOKINETICS

Human brain is a very complex system (the most complex system in the Universe) that implements an enormous set of representations and processes.

Often the contents are organized as maps or as "map-like" structures (see also mnemonic techniques…) in which many data are linked one another to constitute a network of relations. The most studied of these neuronal maps are named *homunculus* (*motorius* and *sensitivus*) and are disposed on brain cortex. *Homunculi* are the projection of body that respects somatic disposition of the different parts, but has not the same proportions, according to the different density of innervations. More innervated parts have a magnified projection on cortex.

Cortex and body are each the projection of the other.

This can be considered a properly double sense biological map.

If we translate the *homunculus* in an iconographic (3D representation, maintaining its proportions and localizations, we obtain a very curious image of a freak body. The deformations reflect strong differences of innervations density. The deformations of *homunculus sensitivus* and *homunculus motorius* are very similar. Evidently it isn't casual: sensory and motor exigencies are parallel…

Cortical *homunculi* make us remember the *homunculus alchemicus* by Paracelsus or, more properly, the platonic charioteer.

However an informational biologic system as the brain needs a projective correlate of the controlled system, with a warranted correspondence point-to-point.

Internal body maps: not only *homunculi*… We must consider the ability of the mind in structuring imaginative maps of the body. They are different from the neuronal *homunculi*, even if these two way of self-mapping influence one another. *Homunculi* functionality contributes to these mental processes and vice versa. We represent in our thinking the spatially placed and oriented body, the detail and the order of its parts, both in static and in dynamic situations. But properly "organic" functions as thermoregulation or others are managed thanks to body maps that our brain builds and continuously adapts. Among the several tasks of the brain there are the regulation and the managing of bodily functions. In order to obtain this goal with effectiveness our brain needs maps representing our body, so it can direct the right impulse to the right target. The brain architecture complies to correspond to different bodily activities. Between the specific neuronal circuit and the part linked to it there is a double sense connection, a two-way feedback loop. Each circuit centre-periphery and back is not an isolate or autonomous system: there is a complex integration that allows to cross information, eliminating ambiguity and optimizing the activity. This work is complex and massive in each moment and continuous in time dimension.

Mental-brain representations (more properly called "simulation" by Barthoz) of (learned) movements constitute a system that can be considered as a map or "map-like". The structure of this map must include somatic/anatomical features combined with its kine-

matic/dynamic functionality in the specific related movements.

The execution of each action requests to be sustained by a mind/brain representation (simulation) the most unitary possible. Due to this we can individuate an engineering model that unifies the factors of a complex mechanical system to compute its functionality.

The study of the human movement is still looking for its own center that can define its specificity, its epistemic identity.

The term "anthropokinetcs" (from the Greek words *anthropos* and *kinesis*) seems to be fully capable of indicating this recently established (in Anglophonic world, but still not existing in Italy) disciplinary area. This term is obviously related to "anthroposomatics", that indicates the field of the studies related to human body, building an organic and unitary frame to organize them in a meta-disciplinary way. The relation between anthroposomatics and anthropokinetics is due to the fact that body is hardly considerable without the continuously "acted actions". Each aspect of body is somehow linked to action and vice versa.

We aim neither to erase the legitimacy of existing studies of many different sciences that are referred to human body and to its actions, nor to create a double of these studies. Instead, we would like to offer them an organic frame to organize their contents and their methods, in order to apply and to communicate them in the best way.

This line of study has the purpose of understanding human body and in particular human action thanks to researches that are capable of integrating biomechanical approach with neuronal one (definable "neuro-mechanics"). First of all this approach originates a dialectic play between these two areas (but many others must be involved, as robotics, semiotics, EEC, IIB) and shows that the Nervous System is a "black box" that, after motor learning, manages sensory-motor information as space-time derivatives and integrals. So the CNS is competent (it owns the necessary acquaintance) as an engineer, even if according to a different formalization, it is based on neuronal sources. Anyway it solves real time and with efficacy the interaction problems, managed as input-output patterns.

Here we propose to follow and to empower the recent establishment of the anthropokinetics, a knowledge of human action that can be applied in many fields: ergonomics, therapy, motor techniques (in work, in sport, etc.), didactics and so on.

Our considerations can be supported by some revealing examples,

Granted that:

1. In practice every type of joint on first approximation allows a bound motion (hinge type kinematic scheme, with one axis of rotation or more) and so a rotatory motion.
2. A lot of movements are obtained thanks to the cooperation of more joints arranged in line (articular chain).
3. In the interaction with the external world we use a lot of linear movements (referred to the free-end of the moving limb).

According to our opinion the connecting rod-crank mechanism (typical of mechanical engineering applied to machines) seems to be the model capable of representing this type of structure-function.

In addition considering that:

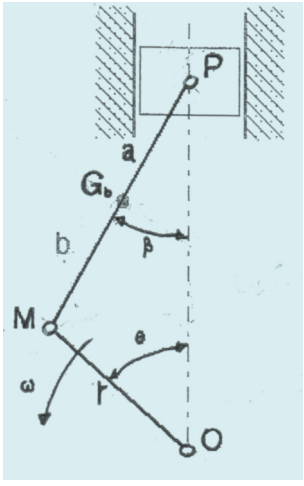
- A lot of actions consist in setting an object or oneself in motion in order to reach a specific position.
- A lot of other actions require the localization of a point of the space that will be reached by an accelerated motion.

We can say that the brain in the control of the movement implements this skill through real time computation processes such as:

i) Conversion step by step of the angles of the joints in the same articular chain in the trajectory of the rectilinear motion and vice versa.
ii) Compatibility of the execution with other factors such as the keeping of the balance, other movements made at the same time, etc.
iii) Derivation. "Problem of the striker": computation of the velocity that the ball needs in order to hit the target, paying attention at the same time to the accelerations that the ball will undergo (due to friction, gravity force, etc.).
iv) Integration. "Problem of the goalkeeper": determination of the velocity and of the position of the ball in a specific moment starting from the observation and from the perception of its accelerated motion.

Derivation and integration in mathematical formalization are implemented through first and second order differential equations that provide the general integral whose particular solution is obtained solving the Cauchy problem.

What the connecting rod-crank mechanism is?




The system made up of three parts connected one to each other by three rotoidal couples and by a prismatic

couple is the typical example:

The first one is called crank. It is hinged to a fixed support (driveshaft in mechanics and first joint of the articular chain in functional anatomy – assuming motionless the rest of the body –). This first hinge is called "O point". The crank rotates around the O point (the bony segment rotating around the first joint in functional anatomy).

The second is the connecting rod, hinged to the crank through a second hinge, the crank button, called "M". The M extremity rotates since it is located at the extremity of the crank (it is bounded). The other extremity of the crank is bounded to a translating part (ex. a piston inside the cylinder). So its motion is a linear motion. The point of connection between the piston and the connecting rod is called foot of the connecting rod. The connecting rod can be compared to the last segment of the kinetic chain in the locomotive system.

The piston is the third element and it translates inside the cylinder. The piston can be compared to the free portion of the limb moving on rectilinear trajectories.

In the creation of a mathematical-dynamic model some expedients are used in order to make the computation easier. First of all the connecting rod is replaced by three concentrated masses located on the foot of the connecting rod P, on the crank button M and on the barycenter of the connecting rod $G_b$. This device allows:

- (applying the mass conservation) the conservation of the moments and the computation of the moment of inertia;
- the substitution of the connecting rod with two masses $\mathbf{m_P}$ and $\mathbf{m_M}$ (respectively located in the foot of the connecting rod and in the crank button) and a factitious moment of inertia called $\mathbf{J_O}$. We use the adjective "factitious" because it doesn't correspond to a real mass distribution, since it is an algebraical parameter (it can be negative too and this is impossible in real moments of inertia).

$$\begin{cases} m_P + m_M + m_{Gb} = m_b \ (masses) \\ m_P a + m_M b = 0 \ (position\ of\ the\ barycentres) \\ m_P a^2 + m_M b^2 = J_b (moments\ of\ inertia) \end{cases}$$

$$a+b=l \Rightarrow \begin{cases} m_P = m_b \dfrac{b}{l} \ (foot\ of\ the\ connecting\ rod) \\ m_P = m_b \dfrac{b}{l} \ (crank\ button) \\ J_o = J_b - m_b ab \ (factitous\ moment\ of\ inertia) \end{cases}$$

This expedient allows an easier (but not less valid) and more elegant study of the problem of the kinetic energy, that allows us to implement the kinematic analysis of the mechanism. The study follows some steps: observing that:

the kinetic energy of the piston is expressed by

$$Kp = \frac{1}{2} m_P v_P^2$$

in which

$$vp = r\omega\left(\sin\vartheta + \frac{\lambda}{2}\sin 2\vartheta\right) \cong r\omega\sin\vartheta$$

$$Kp = \frac{1}{2} m_P r^2 \omega^2 \sin^2\vartheta$$

the kinetic energy of the crank is expressed by

$$Km = \frac{1}{2} J_m \omega^2$$

and that the kinetic energy of the connecting rod is expressed by

$$Kb = \frac{1}{2} m_M r^2 \omega^2 + \frac{1}{2} m_P v_P^{\ 2} + \frac{1}{2} J_0 \dot{\beta}^2$$

The last term is the key element of the treatise since the term $J_0 \dot{\beta}^2$, through goniometric-kinematic considerations, can be expressed referring to the opposite angle, that is the angle of the foot of the connecting rod, observing that

$$\frac{\sin\beta}{r} = \frac{\sin\vartheta}{l}$$

$$\dot{\beta} = \lambda\omega\frac{\cos\vartheta}{\cos\beta} \cong \lambda\omega\cos\vartheta$$

we obtain $J_0 \dot{\beta}^2 = J_0\lambda^2\omega^2\cos^2\vartheta = J_0\lambda^2\omega^2(1-\sin^2\vartheta)$

Ordering the found terms we can obtain:

$$K = \frac{1}{2}(J_m + m_M r^2 + J_0\lambda^2)\omega^2 + \frac{1}{2}\left(m_P + m_P - J_0\frac{\lambda^2}{r^2}\right)v_P^2$$

$$K = K_r + K_a$$

$$K_r = \frac{1}{2}(J_m + m_M r^2 + J_0\lambda^2)\omega^2$$

$$K_a = \frac{1}{2}\left(m_P + m_P - J_0\frac{\lambda^2}{r^2}\right)v_P^2$$

in which the kinetic energy can be considered as the set of the rotating masses and of the alternate masses.

It is clear that the term due to the rotating masses is constant when ⍰ is constant, while the kinetic energy is not constant.

The dynamic of the crank can be expressed as a function of the dynamic of the connecting rod and vice versa. In this way we can deal with a single problem.

This approach in treating the problem in which everything is summarized by the main behaviour of the connecting rod (seen as the junction element between the rotatory motion of the connecting rod and the translation motion of the piston, thanks to the introduction of $J_O$), seems to suggest that the neuronal administration of similar movements in the human body might use or should use unifying expedients similar to this one, or at least with an identical function. A parallel

and separated study would entail an informational load that is difficult to manage, with little chance of success.

The observation of the conclusions of the dynamic analysis of the connecting rod-crank mechanism is more interesting because the rotating forces are distinguished from the alternate forces.

We can have alternate forces of first order and alternate forces of second order.

$$F_r = F_{rm} + F_{rb} = (m_m c + m_M r)\omega^2$$

$$F_a = F_{ap} + F_{ab} = (m_p + m_p)a_p$$

$$a_p = r\omega^2(\cos\vartheta + \lambda\cos 2\vartheta)$$

$$\begin{cases} F_a^{I} = (m_p + m_p)r\omega^2\cos\vartheta \\ F_a^{II} = (m_p + m_p)r\omega^2(\lambda\cos 2\vartheta) \end{cases}$$

So for the balance of the engine we have rotating forces with the rotation frequency of the crank, while the alternate forces are represented by two parts: the first one has the rotating frequency of the crank, while the second one has a rotating frequency that is double. We assume that, in the balance, we can ignore the resistance torque since it is not oscillating type (so it does not cause stress) and the inertia torque of the connecting rod – $J_0\ddot{\beta}$ usually negligible.

Everything is based on mathematical tools: first and second order differential equations, respectively velocity and acceleration, that can be brought back to the following typologies:

$F(x,y,y') = 0$ first order differential equations

$y' = f(x)g(y)$ separable variables

$y' + f(x)y = g(x)$ linear

$F(x,y,y',y'') = 0$ second order differential equations

$ay'' + by' + cy = 0$ $(a,b,c\ \cos t)$ homogeneous

$y = C_1 y_1(x) + C_2 y_2(x)$ general homogeneous integral

$ay'' + by' + cy = d(x)$ $(a,b,c\ \cos t)$ complete

$y = C_1 y_1(x) + C_2 y_2(x) + \overline{y}(x)$ general integral

It is clear that we have to derive in order to obtain the velocity and the acceleration from the time equation, while for the resolution of a second order general integral (the opposite process), some constants of integration are introduced. These constants are resolvable through the conditions shown by the problem of Cauchy.

It is not necessary that the kinetic energy (or the muscular tension - usually in relation with the kinetic energy, but not necessarily coinciding with it) is constant in human movements in which the velocity is constant. The neuronal computation should pay attention to these factors and to their reciprocal relations in order to administrate the action as best it can.

When we talk about computation in general (including the neuronal implementation) we should not think necessarily to the computation mathematically formalized, but we have also to consider the neuronal processing of patterns of impulses, that is the same thing of mathematical computation. The ability in "biological" computation is usually developed independently from mathematical skills, even though they are not necessarily extraneous from biological learning. Mathematical skills can contribute to this process if they flow together in the architecture of neuronal links, allowing the integration of these two aspects, usually called "acquaintance" and "knowledge". Observing how the acquaintance works is the heart of the matter. The central nervous system is no more a "black box" (a system in which only the input-output correlations are known, but not the nature of the processing) that implements the conversion. This process also happens in the brain of illiterate people who do not have the knowledge. As much as to say that the blacksmith "is" an engineer, meaning that his brain is engineer... We have to consider the latin etymology of engineering that gives the possession of the *ingenium* (intelligence, ability, capacity,...) to the man, who is capable of solving effectively his problems.

We hope for the development of a disciplinary area in the study of human movement in which biomechanics and neurosciences are both involved. These two disciplines in tandem might be the epistemic core of this study, but from an epistemological point of view the abandonment of every form of rigid determinism seems to be necessary, adopting the approach of the complexity, of the self-organization, of the emergentism. Some fields such as EEC, IIB, robotic, can be the source of revealing contributions both in the method and in the contents. Robotics in particular has the prerogative of offering a field of application with a strong heuristic valency for human motion, in which, in order to realize the combination of movement of a synthetic physical system and of its independent informational administration, we have to deal with critical problems.

Engineering can offer adequate and effective models for the study of the execution of human action. The connecting rod crank mechanism and, generally, the mathematical-physical approach to moving bodies are meaningful examples. Writing the *"trait-d'union"* to link one another the biomechanical and the neuronal data means reaching the heart of the matter.

The practical purpose aims at building a knowledge, about human motion, capable of increasing the quality and the quantity of the acquaintance in many field of application such as ergonomics, therapeutic practices, motor techniques (in work, in sports, etc.), didactic practices, etc.

When we talk about neural-functionality, we should see this as as a biological function in which abstract

thought instances and cultural instances flow together and vice versa.

The natural location of these researches could be seen in the motor sciences academic departments.

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