Locus-Object Semantic in Digital Cartography (revised in 2018)

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Abstract. One wonders about the contribution of the morphogenetic representation in the field of geography in the cycle understanding: reality, representation, model, and reality. A distinction is made between map and geomap based on the geographical locus-object notion.

Keywords: locus-object, map-geomap, semantic, morphogenetic.

1. Basics and limits of the cartographic representations.

1.1. "Human/information" interface limits in cartography.

General or very specialized, maps are understood and used because they supply useful information for users. They allow them to think, to make decisions or to act. However, precise constraints of manufacture and use appear under this immediate utilitarian aspect. A map is made with a coordinate system and a geodesic projection, it uses an inverse numeric report between the represented objects and the signs which represent them. As the object is large and mutually, we can have small cartographic scale which inverse of geographic scale. The map reading is not immediate because it postulates to a certain degree of abstraction. User should "recognize" the represented information and give a "concrete" geographic sense to the used signs. Which is moreover directly inspired by objects on the old maps, mountains were represented by small hillocks, cities by bell towers with houses all around, fields by rows of wheat ears. In time, these signs became abstract: the green color refocused drawings trees, contour lines substituted themselves for hillocks, etc. However, in the usage, these signs are fossilized. It does not come any more at the idea of a classic modern cartographer to color forests in red while nothing logically opposes to it. Besides, a symbolic sense overlaps in the semiological meaning of the forms: Italy becomes a "boot", Lothringia a "banana", Commonwealth an "octopus", etc. The symbolism of used signs and their permanence have a binding role in the perception of the results in classic cartography, particularly in the techniques of information transmission employed. Maps are also "maps images".

1.2. Digital supplementary constraints.

"Digital map images" are the same constraints as analogical "classical map images": utility, representation by conventional signs, requirements and limitations relative to the system of projection, symbolic drifts. However, in a general way, the passage of the analogical information on the "classic" map in the digital information on the "digital" map moved the constraints. The digitalization of information allows certainly a better flexibility in the map use. But the form[1] is less pregnant on digital maps than on classic maps. The immediate symbolic sense is almost absent; which mean that is can't reappear at the moment or later. The shaping possibility reproductions in relation, in representation and in real time allows to put forward new types of spatial information. These new possibilities are allowed by spatial information use as the satellites images. For example, the invisible spectral information's introduction allows new space representations by the revealing of the geographic objects properties not at once visible. They are also relative to the capacity supplied by data processing to get in touch with the digital map information itself or with other sources. This keeping on touch of use or not to use classic logical methods (Venn diagrams, quadtree, etc.), the geometrical conjugate (Karhunen-Loeve, etc.), or combinatorial methods (arithmetical fusion, linear regression, etc.). All these analysis processes and

[1] Taken in its wide sense, the form is this set of graphic characteristics: hurt, lines, surfaces, textures and colours.

representation to put something forward spatial structures non-directly visible or detected, increase considerably the possibility of geographic information describing. Finally, the digital character of geographic information represented on these maps accelerates considerably their update which can be immediate. All supply a space renewed representation. The combination between these old and new constraints generates new computer and mathematical shaping problems because of geographic object ontological characteristics.

1.3. Object / form / structures report in digital cartography.

The object is represented by an abstract unity, the pixel, the relations of which generate structures which have a preliminary form in any representation. This image generated by the digital information has no direct report with the usual object form. Consequently, the electromagnetic information graphic representation does not make observed objects immediately recognizable; for this it is obliged to wonder about the discontinuities which appear during their digital restitution. Is it differentiations between different objects or inside the same object? The remote sensing digital image requires successive intermediate layers making much more elaborated between the grip of information and its use by the final users. The morphogenetic method of geographic space representation interprets these discontinuities as spatial ones. It detects them by an automatic data proceeding without consideration their preliminary determinations. The spatial discontinuities detected are graphically represented as a contour line map. It is so necessary to look for their geographic meaning as limit or border and here it is ontological problems.

2. Localization and map, locus and geomap.

2.1. General differentiation and geographic differentiation.

On a classic or digital map, the represented objects are material or immaterial: for example, the culture of the wheat, the business of the wheat, the speculation on the stock exchange on the harvests…etc. Each of these objects has a *locus* because, in the surface of the Earth, *object* can't exist without locus. However, the same localization can contain several objects and even several objects in the same object. So, on the quay of a port, a container which is an object with a single localization, can contain several types of objects which have obviously the same localization as the container. The localization of every object is connected so indissociably to the localization of the locus corresponding to each of the objects. The information found in every localization should be semantically differentiated (the object is different from the others) and, besides, spatially differentiated (in the surface of the Earth). In French, indeed, both spellings "différenciation" and "differentiation" are possible, they give the convenience to be able to distinguish the "general differentiation" of the "geographic differentiation", second being a particular case of the first. Finally, one can conceive a locus without any object: the *empty locus*. This last one has an essential role in cartography because it allows to work with localizations which give no information on the locus and about objects. Consequently, on a paper or on a computer screen with localization axes or projection systems, there are only localizations which are quite equivalent.

2.2. Locus-object of geographies.

The biggest envisaged object by the geographies is the Earth; all the macroscopic objects measured in the various scales can be geographic objects. The both initial Whole/Part set logic are:
"… Λ a *finished set* of loci and O *a finished set* of objects on the Earth …"
The *Cartesian product*: $Pc = \Lambda \times O$ is the orderly couples set $p = \langle \lambda \times o \rangle$ where λ belongs in Λ and o belongs in O. A spatial entity is any part of the product $Pc = \Lambda \times O$. Two couples $p_1 = \langle \lambda_1 \times o_1 \rangle$ and $p_2 = \langle \lambda_2 \times o_2 \rangle$ are different and one writes: $p_1 \neq p_2$, if there is a differentiation (written with one t) of at least one of their constituents, the locus or the object. The treated information concerns so, that is the object, or the locus. Four cases can appear for the couple: $<$ locus $= \lambda$, object $= o >$.

Locus-object differentiation (figure 1).

STRONG LOCUS-OBJECT DIFFERENTIATION

$\lambda_1 \neq \lambda_2$ and $o_1 \neq o_2$

WEAK LOCUS DIFFERENTIATION

$\lambda_1 \neq \lambda_2$ and $o_1 = o_2$

WEAK OBJECT DIFFERENTIATION

$\lambda_1 = \lambda_2$ and $o_1 \neq o_2$

LACK OF DIFFERENTIATION (NON-DIFFERENTIATION)

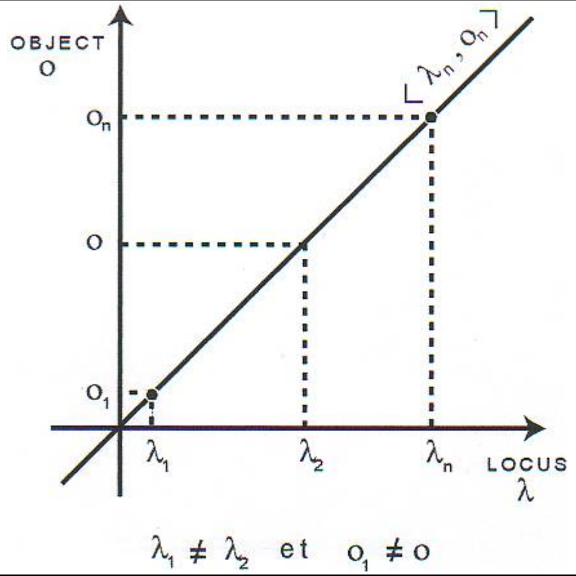
$\lambda_1 = \lambda_2$ and $o_1 = o_2$

A spatial entity is definite as geographic if it contains only two-two differentiated couples, $\langle \lambda_1, o_1 \rangle$ and $\langle \lambda_2, o_2 \rangle$ are two couples of the envisaged entity, then $\lambda_1 \neq \lambda_2$ and $o_1 \neq o_2$. *In other words, on the Earth, any relation between two differentiated locus-object couples is, by definition, geographic*.
A spatial entity is definite as cartographic if it contains only two-two semi differentiated couples, $\langle \lambda_1, o_1 \rangle$ and $\langle \lambda_2, o_2 \rangle$ are two couples of the envisaged entity, then $\lambda_1 \neq \lambda_2$ but $o_1 = o_2$ or $\lambda_1 = \lambda_2$ but $o_1 \neq o_2$. *In other words, on the Earth, any relation between two semi differentiated locus-object couples is, by definition, cartographic.*
If the Earth = T, departure entity of the geographies, is definite as a Whole, then one can give in T the status of set formed by the Part G of the Cartesian product Pc among which the locus and the object are not undifferentiated: $G \subset \Lambda \times O$. *There is no uniqueness in the choice of G but this difficulty is assumed by setting G as wide as possible.*

2.3. The geographic product.

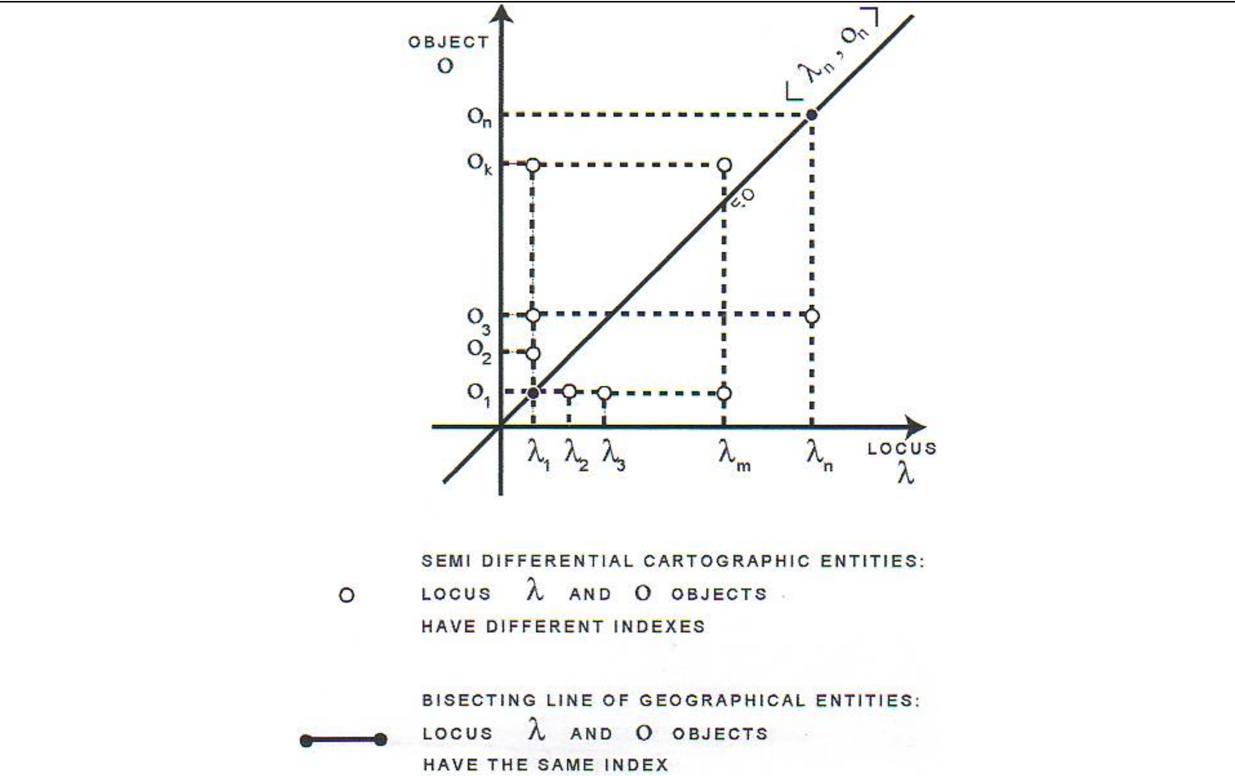
The geographic product $\oplus$ is the Cartesian product $\times$ limitation in the orderly and differentiated couples among which the locus and the object have the same suffix.
$\{ \langle \lambda_1, o_1 \rangle, \langle \lambda_2, o_2 \rangle, \ldots, \langle \lambda_n, o_n \rangle \} = \{ \gamma_1, \gamma_2, \ldots, \gamma_n \}$ where $\langle \lambda_n, o_n \rangle = \gamma_n$
A Whole is, by definition, a geographic entity formed by a set of locus-objects couples of the terms of which have the same suffix.
$T = \langle \lambda_{.x} \oplus o_x \rangle = \{ \gamma_{.x} \}$
A Part is a subset of the geographic entity T.
$P \subset T$
Order locus Λ in the series $\lambda_1, \lambda_2, \ldots, \lambda_n$ and objects O in the series $o_1, o_2, \ldots, o_n$ with an equal number of locus among objects. The geographic product $\Lambda \oplus O$ of Λ and O is, by definition, all the couples $\langle \lambda_1, o_1 \rangle, \langle \lambda_2, o_2 \rangle, \ldots, \langle \lambda_n, o_n \rangle$. Geometrically, if one represents locus on a horizontal axis and objects on a vertical axis, the belonging couples in $\Lambda \oplus O$ are situated on the bisecting line. The couples of the geographic product $\Lambda \oplus O$ are always then two-two differentiated.

Differentiation by the geographic product (figure 2).



If a geographic locus-object is not directly perceptible one can substitute it by one of the recording properties, for example, the wavelength. If this property is common to numerous different locus-objects one can so substitute these locus-objects by their properties by an operation of "metonymy". It is about a word by which one expresses the "locus-object" concept by "wavelength" term means which indicates then locus-object to which it is connected by a necessary relation of differentiation. The effective Cartesian product × part for T considered as the Earth means considering the couples $\langle \lambda_1, o_1 \rangle$, $\langle \lambda_2, o_2 \rangle$ where $\lambda_1 \neq \lambda_2$ with $o_1 = o_2$. From the "distance" point of view, the geodesic is reducible in the cartographic (as the example of the differences of wavelength confirms it) and consequently the problems of the cartographic distance (between locus) and those concerning the geodesic distance can be treated in the same way. Also, "metonymy" is usually used to substitute a geographic locus-object which is not directly noticeable by an object the properties of which are saves. For example, locus can be locus by localizations in which are saved multiple statistical data. These data are then considered as "commons" with numerous different locus-objects linked by a necessary relation of differentiation. The effective Cartesian product × part for T considered as the Earth means then considering the couples $\langle \lambda_1 , o_1 \rangle$, $\langle \lambda_2 , o_2 \rangle$ where $o_1 \neq o_2$ with $\lambda_1 = \lambda_2$. As first, from the "distance" point of view, geodesic is reducible in the cartographic (as the differences of wavelength confirms it). Consequently, the problems of the cartographic distance (between locus) and those concerning the geodesic distance can be treated in the same way.

Geographic and cartographic entities (figure 3).

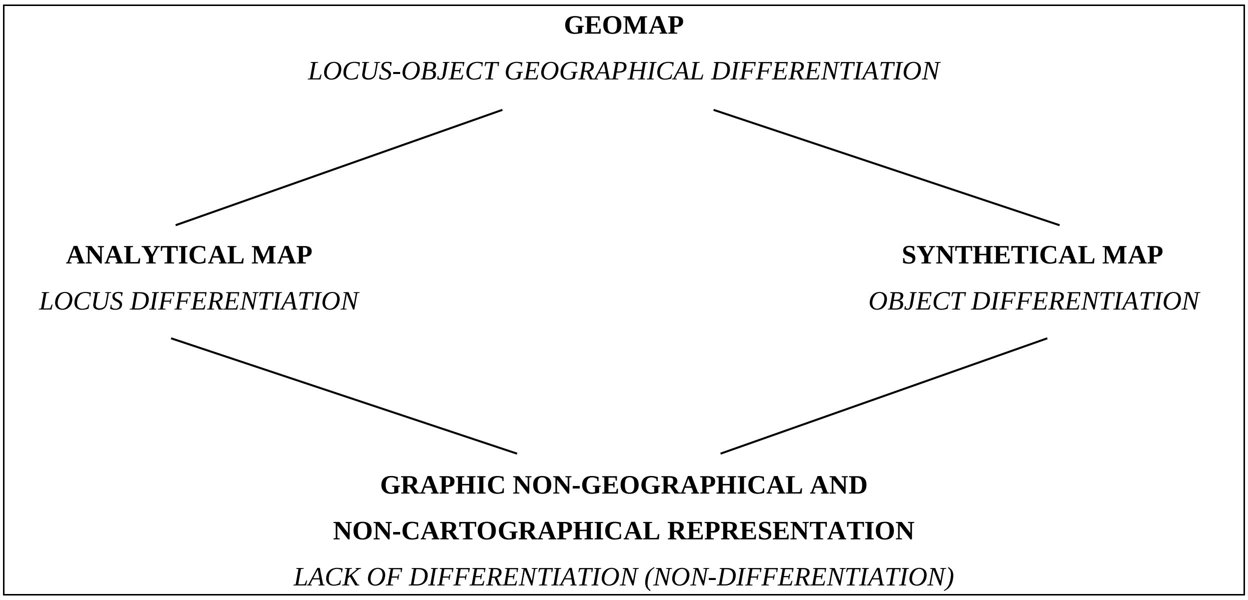


A couple $\langle \lambda_n, o_n \rangle$ where λ and o has the same indication is a geographic locus-object definite as a *Whole*. The differentiated couples: $\langle \lambda_1, o_1 \rangle$, $\langle \lambda_2, o_2 \rangle$, …, $\langle \lambda_n, o_n \rangle$ with $\lambda_1 \neq \lambda_2$, …, $\lambda_{n-1} \neq \lambda_n$ and $o_1 \neq o_2$, …, $o_{n-1} \neq o_n$, have the same indications group together on the bisecting line (figure 3) represents all the geographic Whole. A geographic entity contains only two-two differentiated couples $\langle \lambda_1, o_1 \rangle$ and $\langle \lambda_2, o_2 \rangle$ with: $\lambda_1 \neq \lambda_2$ and $o_1 \neq o_2$. Cartographic spatial entities are formed by semi differentiated couples taken two-two. If loci are differentiated: $\lambda_1 \neq \lambda_2$ but not objects: $o_1 = o_2$, the entity is an *analytical map* which indicates an object in a set of loci: $\langle \lambda_2, o_1 \rangle$, $\langle \lambda_3, o_1 \rangle$, …, $\langle \lambda_m, o_1 \rangle$. If objects are differentiated: $o_1 \neq o_2$ but not locus: $\lambda_1 = \lambda_2$, the entity is a *synthetic map* which groups together a set of differentiated objects in a single locus: $\langle \lambda_1, o_2 \rangle$, $\langle \lambda_1, o_3 \rangle$, …, $\langle \lambda_1, o_k \rangle$. Type entities: $\langle \lambda_m, o_k \rangle$ and $\langle \lambda_3, o_n \rangle$, formed by taken two-two couples from which λ locus and o object suffixes differ, are *not geographic* and *not cartographic* spatial entities.

2.4. Map and geomap.

Since locus-object and localization are different but connected, it is evident that their separate or simultaneous use is going to generate different types of representations. If locus is *differentiated*, but not objects, one says that the couple is “weakly differentiated” by locus. It is the case of the information that only indicates a category of objects: for example, the wrinkling and the tectonic accidents (geologic locus), the borders of States (political locus), the figures of populations (demographic locus), the electromagnetic impulses (digitized locus), etc. Both are differentiated only by the position where they are and consequently it is possible to reduce locus to localizations. This information generates analytical maps as initial morphogenetic maps (to see 3). On the other hand, so only objects are differentiated, one says that the couple is “weakly differentiated” by objects. It is about different elements concerning non-differentiated locus. Differentiation is generated by the object (weak differentiation), all the locus become confused, and on the same map it is possible to represent objects in every localization. Object localizations allow to represent the locus-objects only objects of which are differentiated: they are synthetic maps with multiple information in every localization as “pie chart” maps or still intermediate morphogenetic maps (to see 3). Finally, if locus and objects are both differentiated, so the couple is “strongly differentiated” by locus and objects. It is the case of the final morphogenetic maps (to see 3). On the contrary, if locus and objects are non-differentiated, one says that the couple is “non-differentiated”. Abstractly, in economic theory, a homogeneous “transport land plain” where one can move in the same cost indifferently in all the directions by generating identical form transport systems is a geometrical space which is differentiated neither by locus nor by objects. It is the case of numerous voluntarily created spaces in the surface of the Earth to fill a condition of non-differentiation: protected prices, stake in perfect competition, customs protection, by uniform accessibility, etc. Things being what they are, if in a given scale these spaces are not differentiated geographically, they can future in another scale.

Geomaps and maps (figure 4).



3. The morphogenetic method of geographic representation.

3.1. What is represented on a digital image?

A current problem in classic cartography consists in trying to represent in the same localization different objects with locus for each. We have the same problem on digital maps: all objects were identified and represented by a sign. Being this if, at first, use only electromagnetic impulses as in the morphogenetic map case, then the inverse problem is in front. In knowledge, how to identify and to represent different “concrete objects” from a “physical locus” single type? Or still, how identify concrete objects from recording variations of locus single type with multiple localizations? Exposed morphogenetic method of geographic representation answers this problem of geographic object-locus recognition and identification. It generates spatial discontinuities morphogenetic maps which are representations of geographic space structures. From their revealing the locus-objects recognized and identified by their limits research. It makes morphogenetic geomaps. The method uses optical remote sensing data which are the measure representation of geographic locus-objects electromagnetic reflectance and their relations: the geographic space. It is the combination of various reflectance measures that gives substance to the locus-objects couple. Indeed, data supply a rarely homogeneous spectral image of locus-objects. Each of these images is a pixel set which concerns differentiated locus and reflection of a complex of locus-objects, this set integrates a multiple of attributes into a single localization. It is what wakes the wealth and their representation uses two successive processing. To begin, the use of Karhunen-Loeve conjugates aims to concentrate on first axis the maximum of variance information. This concentration of information improves the geographic locus-object discrimination capacity. The statistical values relative to the other axes constitutes a information “package” which by their unpublished contents can enrich the knowledge of territory. Then, local statistical operators allow to adjust geographic information contained in satellite images with regard to the studied spatial level. These mathematical operators serve for making setting operations by neighbourhood and convolution by variable size mobile windows means. The choice of mobile window size determines the neighbourhood order degree. It fixes aggregation or disintegration spatial level of the spatial information contained in the remote sensing image. The satellite image's geographic information face to face the studied spatial level is optimized. The purpose of these two processing is to statically optimise the geographic information contained in remote sensing image. Finally, recognition, spatial discontinuities extraction and their indexation by a digital attribute are made by morphological transformation. The morphological operation consists of a thinning down associated to a convergence with Golay H structuring element. It obtains a geographic space representation of spatial discontinuities contour lines. Each of it belongs to a spatial entity which forms a locus-object couple. There are at the same time localization in every of it contour line, a quantified measure and expression of a geometry. The *edge* localization, that is the discontinuity which is the locus-object limit gives at the same moment the form of the objects and its localization. The intrinsic spatial discontinuities localizations in the object confer it morphology and it differentiation degree with regard to the other objects. Spatial discontinuities localization coordinates generate a representation of the morphology and the geographic space and each locus-objects element (figure 5).

Representation of the geographic space by electromagnetic reflectance measurement (figure 5).

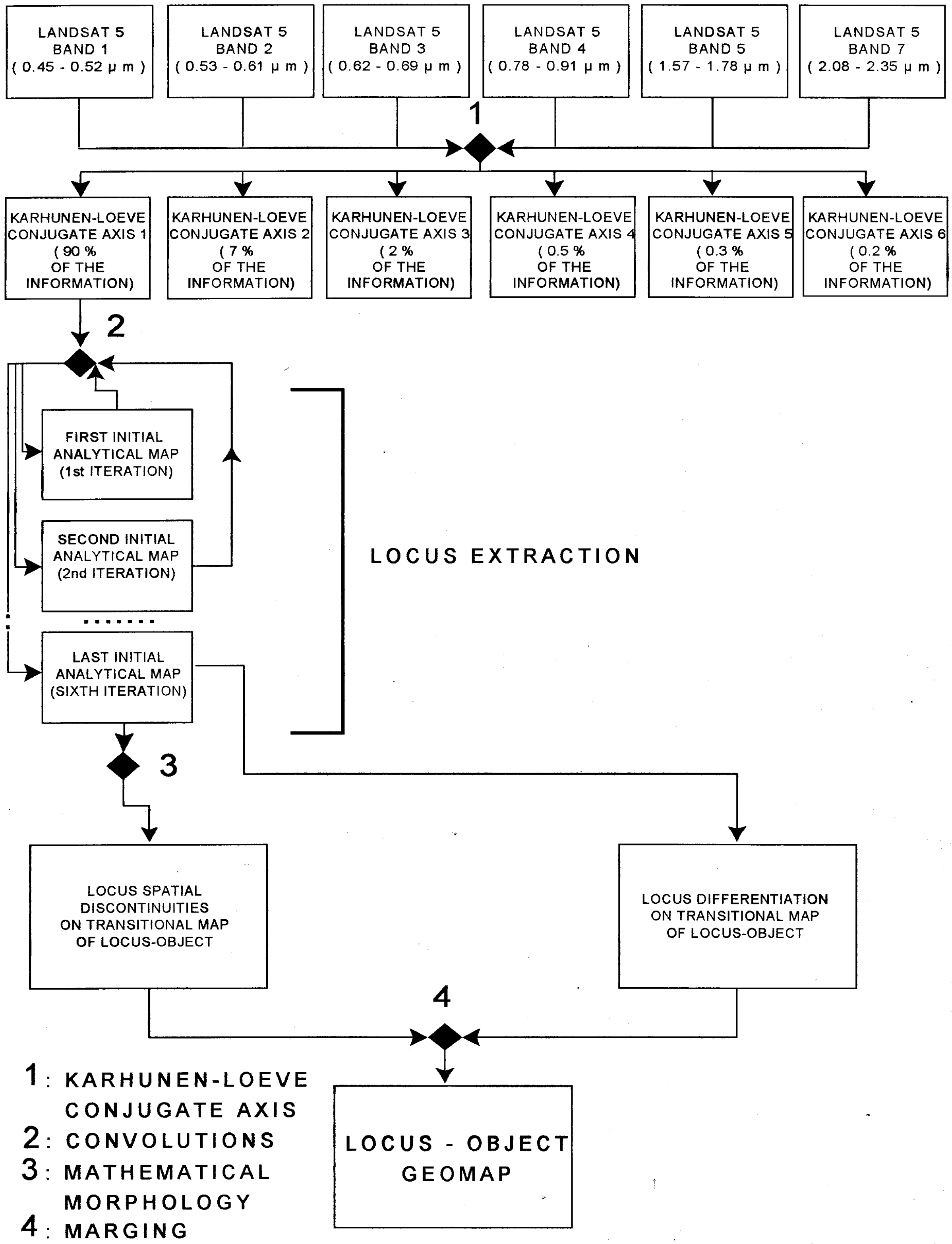


FIGURE 5

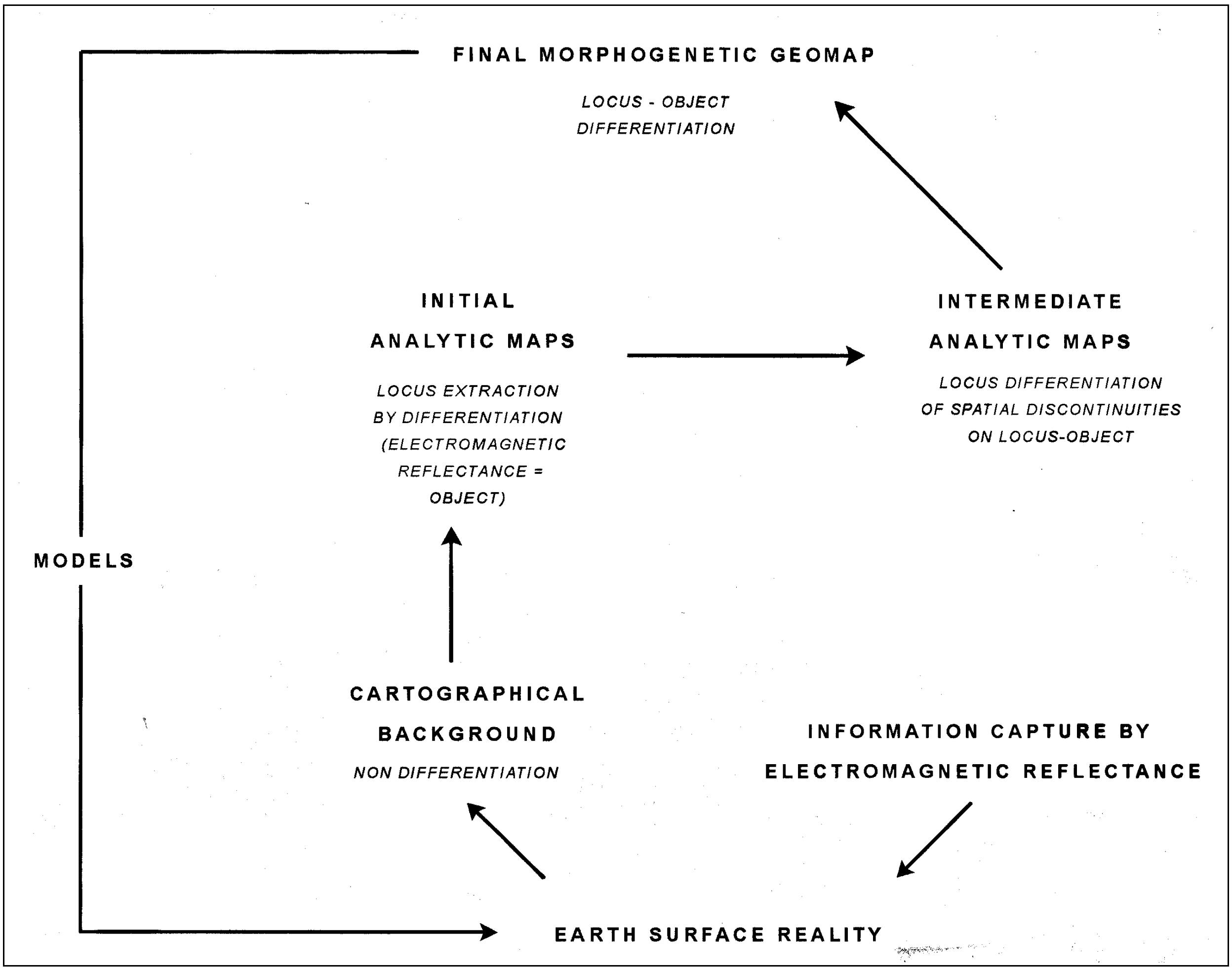
GEOGRAPHICAL SPACE REPRESENTATION BY ELECTRO - MAGNETIC REFLECTANCE MEASURING (LANDSAT 5 TM)

SEBASTIEN GADAL, 2000

3. 2. Information, reality, representation, reality, geographic circuit.

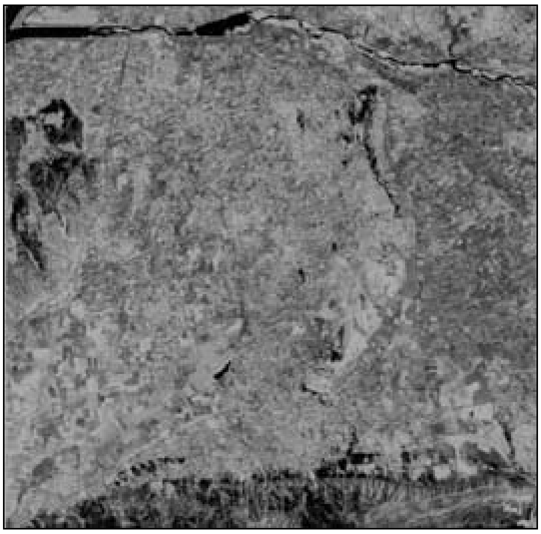
Map images which are made by geographic morphological method representation are included in a circuit which dreads the reality in an electromagnetic way, restores it by means of pixels and of differentiated forms, represents it by successive “map images” (figure 6), which supply a contour lines space perception under the geomap shape by the locus-objects differentiation criteria introduction. They can serve as reality modelling or as making tool on this last one.

Integration model of morphogenetic map (figure 6).

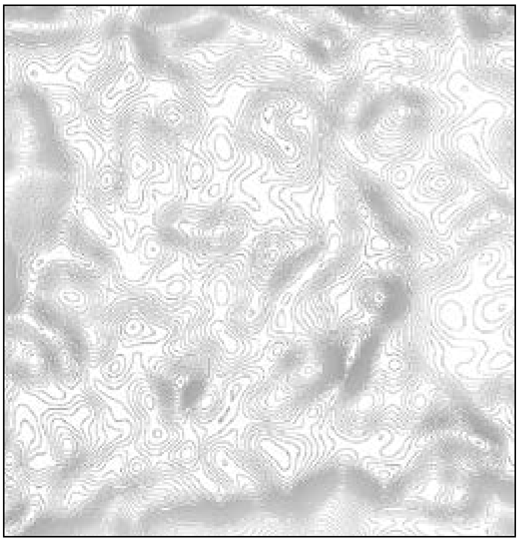


This reality construction is made from electromagnetic measure of Earth's surface data images (figure 7). It is conditioned by the physical and geometrical characteristic of sensor measure. Spectral resolution (spectral band number and wavelengths covered) and spatial resolution (pixel size) recover fundamentally from “spatial statistical unity/geographic information” dialectic (localization/locus-objects dialectic). It elements constitutes a first filter by produced data and used type for map made, then geomaps. Data used influence considerably the geographic space representation and its reality. They have an *a priori* non-differentiation character which does not alter the geographic reality and represented character in remote sensing image. “Localization/locus-objects” report has an influence on the morphological character of the locus-objects, that is on its limit localizations. It makes of the geographic object a locus for borders and for multiple dimensions. Finally, the morphogenetic field (figure 8) is a geographic space perception which is represented under the field shape, that is geographic differentiation gradient which expresses a radiometric differentiation intensity of geographic space. It a fitted locus-object set and a representation of the geographic space structures.

Landsat 5 TM satellite image.
The Comtat Venessin (Avignon, South of France)
(Figure 7).



Morphogenetic field of geographic space (bi-dimensional analytical map).
The Comtat Venessin (Avignon, South of France) (figure 8).



The geographic morphogenetic model is a spatial radiometric gradient of discontinuities concerning structures and geographic phenomena detecting by satellite sensors. The geographic space morphogenetic field is likened to a radiometric contrast gradient of landscape. It defines a continuous functional space: the geographic space. The discontinuities contour lines shed light on something intensity of the landscape geographic differentiation. They are considered as spatial discontinuities in the direction where they are relative in the "space" of satellite image. This method is a bearer paradox on the nature of the discontinuity. The spatial discontinuities (or geographic) in their normative acceptance bound and differentiating the geographic objects.

3. 3. Morphogenetic model, a spatial analysis supports.

The geographic space model in a morphogenetic field, which is in a radiometric discontinuities spatial gradient, refer to the locus-object problematic. The model has a peculiarity to operate a weak differentiation by locus ($\lambda_1 \neq \lambda_2$) where is identified all the geographic space locus. The geographic space representation of morphogenetic field is an *analytical map*. It represents locus which are structured in a hierarchic and topological way. By combining objects identification, that is the weak geographic differentiation by the object, we obtain a *geomap*. The space is geographically differentiated at the same moment by the locus and the object (figure 9). We definite a strong geographic differentiation. ($\lambda_n \neq \lambda_{n+1}$ et $o_n \neq o_{n+1}$) (figures 1 and 2).

Geomap example.
The Comtat Venessin (Avignon, South of France) (figure 9).

The *morphogenetic geomap* is a structure and locus-object representation of geographic space (figures 5 and 6). It has an originality to give at the same time quantitative and qualitative geographic space perception. Quantitative: it is a frame of spatial differentiations and interrelations between locus-objects measure; qualitative then: it allows to identify geographic discontinuities, spatial interrelations between locus-object characteristics, classifying and formalizing them.

Conclusion.

They are “classic” or “digital”, the geographic graphic representation is of the same type. But “map images” made by morphogenetic representation method allow to integrate into a unique operating circuit all the map types and practical geomaps. What is usually separated in the classic representations can be done by the same user. No to introducing a gap between “classic geography” and “modern geography” the locus-geographic object concept allows to understand by using morphogenetic representation method the circuit established between all the types of geographies and geographic representations (maps and geomaps). This conception also allows to understand that locus can be metaphorically considered as fourth dimension of the geomap. It is present in all levels of the reality, information, representation, and reality circuit controlled by user. This circuit allows to understand from geographic representation being exclusive, the morphogenetic geomap at the moment in the circuit, a “model” realizing the geographic locus-object theory. But what remains essential from scientific point of view, it is the *equivalence between the “model” and the verified “reality” by going through reality, representation, model, return in the reality circuit.*

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