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Characteristics of J. Bertin's graphic system from the perspective of heuristic and abductive reasoning methods

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Abstract: The work of French cartographer J. Bertin is multifaceted and is now well-recognized in the field of infographics. His discussion of graphical representation is not only limited to the pursuit of clarity of content and immediacy of communication in graphical representation, but also includes heuristic and abductive ways of thinking, which concerns one's own hypothesis-discovery reflective process. However, until now, discussions in the field of cartography have mainly focused on the technical aspects of graphical representation and the examination of heuristic and abductive reasoning methods has been insufficient, even though the digitalization of information and artificial intelligence technologies are now in place to support such an environment. Therefore, we review Bertin's articles and books in an attempt to re-evaluate them from the perspective of heuristic and abductive reasoning methods. Although Bertin seems to have proposed a method of visual representation that emphasizes a monosemic system, in fact, methods to stimulate vivid abductive reasoning and discovery through graphics are central to his interests; he should be seen as having pursued theoretical frameworks, such as visual variables, to effectively advance these methods. His graphics is not static but a dynamic process of graphic thinking to conceive images that require further development.

Keywords: J. Bertin, semiology, exploration, heuristics, abduction

1. Introduction

This year (2025) marks 26 years since J. Bertin (1918-2010) was awarded ICA's Carl Mannerfelt Gold Medal in 1999. His work is multifaceted and has been recognized in the field of infographics, which goes beyond cartography, to convey information through graphics (Rendgen, 2012). The author proposed a diagrammatic representation of the flow of his work as three stages of development (Morita, 2011): 1) the semiotic approach, 2) the map as a process, and 3) cartographic discourse. However, the development of this process is not limited to the pursuit of clarity of content and immediacy of transmission in graphic representation, it also includes the heuristic and abductive reasoning methods of graphics. Nevertheless, until now, discussions in the field of cartography have mainly focused on the technical aspects of graphic representation and the examination of heuristic and abductive reasoning methods has been insufficient. This is even though the digitalization of information and artificial intelligence technology has been well-developed, and the environment is now in place to support such technologies.

In this paper, therefore, we review Bertin's articles and books from the latter perspective and attempt to examine them from the viewpoint of how, and under what circumstances, he developed his heuristic and abductive reasoning methods. Finally, we discuss how they relate to the basic concepts that characterize cartography (exaggeration, omission, figure-ground, superimposition, juxtaposition, rotation, scale transformation, projection transformation, symbolic transformation, etc.).

2. What is Abduction?

Communication theory is one of the theories used as a historic reference when creating maps. Maps are a visual language and, like words in natural language, they are a method of conveying what one wants to say in the form of a map with cartographic symbols instead of written words. In this process, a model is usually created based on a situation where what is to be said is predetermined (Figure 1).

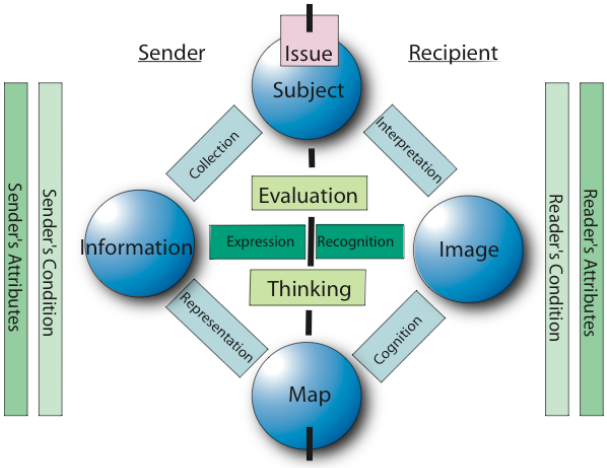

Figure 1. Cartographic Communication

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The diagram for the notion of map-based communication was proposed by R. Ratajski (Ratajski, 1973), adapted by the author (Morita, 2005). For map-based communication, there is a sender and a recipient. When the sender wants to send map information to a recipient, the sender must fix a subject and collects information to build a map. Once sufficient information has been collected and arranged, the next step will be to design map symbols and append a legend. It is through processing spatial data in this order that the information which the sender wants to convey is transformed into a map. Understanding the context of the map by the recipient begins with the perception of a spatial image forming in the brain after viewing the map. This is a cognition process using the distribution pattern of map symbols.

In recent years, however, the digitalization of information has resulted in the creation of context-sensitive maps, creating a dynamic situation in which what needs to be conveyed or understood changes from moment to moment. For example, when using a car navigation system or smartphone navigation system, information is given at every moment, indicating the direction to go. On the other hand, however, depending on the situation, we are often faced with an inconvenient or misalignment of information that is clearly not what we wanted or may even be incorrect. In addition, daily information retrieval, which is performed at will or as needed, is also usually accompanied by trial and error. A discussion of the process of hypothetical reasoning (abduction) is also relevant.

Abduction is one of the three basic patterns of logical thought advocated by the American philosopher C. Peirce (1839-1914) and is one of the three categories: induction, deduction, and abduction (Stanford Encyclopedia of Philosophy, 2021), (Hartshorne and Weiss, 1965). There are two types of information that can be obtained through maps: those that can be understood by looking at them and those that can be inferred through looking at them, testing hypotheses, and developing the imagination. If necessary, these processes are dynamically developed through iteration towards the expected value by trial and error. This is the definition of ‘abduction’ but this ability to reason through graphics, which maps can provide, has not been explicitly addressed as a ‘method’ in the past, despite its great advantages. Although the act of map reading generally assumes that the content to be read is predetermined, the task is how to read and confirm it accurately. Four representative documents relating to Bertin were studied, to help us to understand the objectives of his method and how they can be used.

3. Re-evaluation of Four Bertin Documents

In chronological order, Bertin's major works are: "Research in Graphics" (Bertin, 1952), "Semiology of Graphics" (Bertin, 1967), "Graphics and Graphic Information Processing" (Bertin, 1977), and "Universal Historical Atlas" (Bertin, 1997). With reference to these four works, we can trace their characteristics from the perspective of the use of heuristic and abductive reasoning processes.

3.1 "Research in Graphics" 1952.

Fifteen years prior to the publication of "Semiology of Graphics" (1967), Bertin published "Research in Graphics”. This is a monograph on "Paris and its metropolitan area" that was being conducted at CNRS (Centre National de la Recherche Scientifique) at the time and was published by PUF (Presses Universitaire de France) as a book in the Contemporary Sociology series. The monograph is divided into two parts: "I. The Social Space of the Metropolis" and "II. Methods of Exploration in the Study of the Metropolis" and contains numerous graphics, including aerial photographs. Bertin oversaw the creation of the graphics and the reasons for such a method of representation, which he summarized in his paper "Research in Graphics”.

This paper already contains various elements of subsequent theoretical developments, as well as visual variables. Let us examine these various elements in terms of abduction.

(1) "Social Space of the Metropolis": The first volume attempts to extract various issues from the Paris region, mainly from a sociological perspective, under the prevailing proposition of how to cope with the population concentration in metropolitan areas after the end of World War II. In general, in regional planning, for example, in the Paris Regional Plan (District de la Région de Paris, 1965), the development of road networks was planned by predicting the areas where there was a shortage of physical infrastructure, such as transport networks, mainly through engineering methods, such as supply and demand surveys. On the other hand, it should be noted that this study was an attempt to visualize how social phenomena (which are not physically visible) are distributed, using thematic maps.

The figures used here include 10 aerial photographs, 1 topographic relief map, 84 statistical distribution maps (including 9 concentric circle base maps), 12 schematic maps, 8 location maps, and 1 ‘change map’ composed of statistical diagrams.

The aerial photographs are simple black-and-white photographs with the outlines cropped according to the area of interest. They are simple reference materials because they do not include notes, place names, or other elements to guide the reader.

The topographic relief map was created by giving a width to the contour lines and then illuminating the strip with light from an oblique direction. The results of map reading are hypothetical, as inferences are required to understand the overall structure of the terrain, but this is not discussed and so the map is treated as a reference map.

The statistical distribution maps show the distribution of the data using proportional symbols of size, value, or dot arrangement, and are intended to show the situation as a distribution map for the issue indicated by the name of each map. It is possible to compare them, in terms of their similarities and differences but, since they do not

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superimpose onto the referential background map, they do not infer the cause of their differences.

The concentric circles are based on the Chicago School's theory and represent the distribution of population and urban areas as radial-concentric forms. Since the distribution is naturally skewed, the question arises as to what influences this skewed distribution.

A schematic diagram simplifies the distribution and shows the zones by using a line, or shows the relationship between them by changing the line type or using arrows, etc. This provides a hypothetical answer to the theme indicated by the name of the map.

A location map is a reference map for the location of a target space, showing the basic elements of the space by place names, street networks, railway stations, etc.

The change map shows the increase or decrease between two periods, using a pie chart of the symbols on the statistical map; this is only one example.

Among these, topographic relief maps, concentric circle maps, and schematic maps stimulate hypothetical inferential thinking, while the other maps are structured to confirm the events indicated in the titles of the maps through graphical representation. The latter, however, also attempt to show the characteristics of metropolitan space in an analytical manner and the setting of the title is both hypothetical and inferential (e.g. the change over time in the distribution of movie theatres); the structure is verified through the map.

(2) "Methods of Exploration in Metropolitan Studies": The second volume explains the rationale for the various methods of analysis used in the first part, comprising:

a) sociological research fields on urban space
b) aerial photographs in urban studies
c) research in graphics
d) comparison of small-scale maps
e) statistical use of resident registration information
f) cities, districts, residential areas, and buildings
g) streets and stores
h) examples of research projects for comparative studies (suburban and metropolitan districts, district-level life studies, district commercial facilities, and building studies).

Among these, the theory described only uses figures in the (c) research in graphics section, written by Bertin.

This section covers data selection, scale selection, background graphics preparation, and data representation. In the latter, "the field of graphics" consists of the comparison, superimposition, and combination of data (graphic analysis). It should be emphasized that graphics have the characteristic of being able to be shared with others beyond their mere representation. Of these, the following are illustrated with graphics:

a) a background map of concentric circles in the central 70 km area of Paris consisting of rivers, a rail network, and the Paris city boundaries
b) a district-level base map of Paris
c) background maps for work and publication
d) distribution maps of the small and large symbols corresponding to zones
e) diagrams for setting the radius of proportional circles using a single logarithmic scale
f) representation of area shading
g) 3-6 levels of value symbols
h) how to assign value symbols using frequency distribution charts
i) how to fill in pie charts
j) a comparison of symbol design using shapes, value, and highlighting contours
k) a comparison of distribution charts using shapes, value, and highlighting contours.

Of these, the composition of the background maps and graphic analysis is related to the process of hypothetical reasoning and its verification using graphics, and there is no conscious emphasis yet on them here. In other words, the focus is on cartographic representation, i.e. the organization of the correspondence between information and symbolic representation. Moreover, although the results shown are not necessarily in a state of heuristic assertion, it may have been meaningful for these to be presented all at once, in a list format, to share a basic image of the current situation.

3.2 "Semiology of Graphics" 1967, 1973, 1998 (reprint), and English editions 1983, 2010.

This book was Bertin's first published work. The manuscript, which was in printed form prior to the publication of this book, was titled "The Semantics of Graphics" (Archives National (AN) material). It embraced all the main elements, including visual variables, but no meta-theoretical semiotic explanation was given as to the semiology of graphics. In other words, it contrasted a semantic approach with a syntactic linguistic approach (Morris, 1938), attempting to show the correspondence between the way that symbols are used and the meanings arising from them; contrasting good and bad expressions for the same objective. In the final manuscript, a semiotic explanation was added to the first part of the introduction and the title was changed to "Semiology of Graphics".

The first part, "Semiology of the Graphic Sign-System", explains how graphics work as a sign system from a syntactic point of view, whilst the second part, "Utilization of the Graphic Sign-System", attempts to show what kind of expressions succeed and what kind fail when the sign system is operated from a semantic point of view. The specifics are discussed below.

In the first part, the definition of graphics is first developed as an introductory section and the semantics entrusted to signs are classified as: monosemic, polysemic, or pansemic. The receptive organs for signs are divided into visual and auditory, with graphics being monosemic and music being auditory and pansemic.

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Bertin also stated that auditory perception is a one-dimensional (time) change and only one sound can be recognized at a moment's notice, while visual perception is a two-dimensional (plane) change and the identification of signs, and their relationships can be observed at a moment's notice. Therefore, at this stage, the graphics act like a stimulus-response system and do not give the image of a dynamic abductive reasoning process.

However, at the end of the introduction, there is a section that describes the future of graphics, which states that the era in which the sign is fixed by nature will end, and that it will evolve into 'living graphics' that can be used by anyone by superimposing, juxtaposing, transforming, rearranging, and other operations, to create new groupings and classifications. An era of "living graphics" will evolve, which can be used by anyone. In other words, he refers to the possibility of dynamic images using information systems. The book then goes on to discuss the need to determine the nature of the graphics required for this purpose.

The first part is organized as follows: I) Analysis of the information; II) The properties of graphic systems; and III) The rules of the graphic system. This part shows the relationship between the nature of information, the graphic system that represents its content, and the vision that accepts it. The relationships between them are developed from the basic viewpoint that high readability is desirable, and the structure is such that what is to be represented is given in advance.

In the second part, the following basic frameworks are explained to classify the problems to be solved by graphics: first, representation types, such as graphs, networks, and general maps; second, appropriate representation according to the number of visual variables; third, representation according to information levels, such as distinction, order, and quantity; and fourth, representation according to the scale of the number of indicators to be handled and representation in terms of points, lines, and zones.

After explaining the basic frameworks for these graphic presentations, the second part is organized as follows: I) Diagrams; II) Network; III) Map; and IV) Text, tools, and graphic documents. The structure of these sections is to categorize the various graphic techniques and to examine what kind of expression can convey the semantic content that should be indicated by each technique. The semantic content is nominal, ordinal, and quantitative, and their desirable symbolic expressions and organizational methods of operation are developed. In other words, it talks about syntactics and semantics, according to its purpose. Therefore, the reason why such a graphic representation is chosen, the search for the setting of the subject, the hypothetical reasoning process, and the trial-and-error process used in the building of graphics are partially mentioned in part III. However, there are no in-depth references to them.

3.3 "Graphics and Graphic Information Processing" 1977, and English edition 1981.

In the introduction to the previous book, "Semiology of Graphics", there was a vision that graphics will evolve into an era of living graphics that can be used by anyone, as new groupings and classifications emerge through their manipulation. This book attempts to provide a methodology for this perspective. However, it is not a direct development of the process of using information processing software but, rather, a step-by-step explanation of the principal procedures for using graphics.

At the beginning, an example of a hotel is presented, where 20 different indicators are given over 12 months in one table. By visualizing them as a visual matrix and arranging the rows of indicators that seem to be related to each other, so that they are adjacent to each other, the structure of the relationships between the indicators becomes visible as a coherent visual structure. This structure of relationships guides the decision-making process for hotel management. The usefulness of the function of the graphics is demonstrated by contrasting the functions of the numbers and the visual matrix. Then, the various methods of utilization and their logical structures are developed in the chapters that follow:

A. Postmortem of an Example
B. Graphic Constructions
C. The Graphic Sign System
D. The Matrix Analysis of Problems and the Construction of a Data Table.

A. Postmortem of an Example consists of:

1. The stages of decision-making
2. The aim of graphics: a higher level of information
3. The three successive forms of graphic application.

This describes how graphics are useful to people as a graphical language through various stages of decision making.

B. Graphic Constructions are composed of:

1. A "synoptic" of graphic constructions
2. Permutation matrices
3. Ordered tables
4. Re-orderable networks
5. Ordered networks: topography and cartography.

This classifies the nature of graphics, largely according to whether they can be dynamically sorted and manipulated or visually grasped; it describes a method of creating groups. In other words, it discusses heuristic operations and the process of reasoning in visually generated hypotheses and not the pursuit of effective representation of predefined representational objectives that have been common until now.

C. The Graphic Sign System consists of:

1. Specificity of graphics
2. The bases of graphics
3. Variables of the images: plane, size, and value
4. Differential variables

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5. The law of visibility.

This is an attempt to theorize the characteristics and structure of graphic representations as a graphic language, from the perspective of semiology. It logically explains how the dynamic movement of intention, such as discovery and hypothetical inference, is made possible as visual information.

D. The Matrix Analysis of Problems and the Construction of a Data Table consists of:

1. The apportionment table
2. The homogeneity schema
3. The pertinence table
4. Applications of matrix analysis.

This describes how to assemble the information to be considered as data for the treatment of the problem and how to derive hypotheses from it. This part of the book is significantly related to the exploration of the problem in the example in Section A but the reader is not yet ready to deal with it at that stage of the book, which is the introduction. Thus, it is arranged in this way. Incidentally, if the problem is to be explained through data, those data must share a point of comparison with each other. It is also argued that, to do so, they must have a matrix-like structure. Matrices can be shown as a visual structure and the whole range can be shown from the beginning. It is also possible to check for missing data. If groups that can be understood through selection and processing can be extracted from them, the relationship of their arrangement with the surrounding data will also become significant and the validity of the processing can be explained. For this purpose, it is assumed that it is sufficient to clarify the type, scale, and correspondence of all components by means of an assignment table, to arrange all the information that can be derived by means of a homogeneity diagram as a table, and to list and show the deductive data and necessary preliminary calculations that should be derived as a hypothesis by means of a correspondence table.

This method is not like numerical analysis, in which the final answer is given unambiguously but, rather, it is a method that stimulates new discoveries through trial and error because it uses visual perception (the response of the sensory organs) in the form of a list diagram.

Subsequently, these ideas were gradually incorporated into information systems. They can be seen to move in two main directions (Morita, 2019). One is to give the recommended process as a default, so that results can be obtained automatically and immediately, while the other is to break down the analysis into steps and ask users to make decisions in each section, obtaining results through a series of hypothetical inferences. It should be noted that the style of use depends on the purpose of the analysis and that information systemization, especially when dealing with graphics, is not synonymous with automation.

3.4 "Universal Historical Atlas" 1997.

This book was Bertin's last comprehensive work, in which he attempted to develop world history using a common world map for each period. In general, history follows the flow of the topics covered with the passage of time but this book, as the subtitle suggests, attempts to show what was happening in different parts of the world at the same period using a world map, and how it developed with the flow of time, arranging world maps as a film strip.

In the previous book, "Graphics and Graphic Information Processing", the concept of a matrix structure consisting of vertical and horizontal axes is often used and, in this book, equally, the world (which is a spatial expansion) and the epoch (which is a temporal development) are related on the horizontal and vertical axes. The basic frame of the world is made to develop as homogeneously as possible. To show the characteristics of these transitions in an easy-to-understand manner, the world map is arranged like a film with 48 frames (4 frames x 12 chapters); each representing a double-page spread of the entire world’s history. This makes it easy to cross-reference each period and the overall flow of world history. The density of events increases as one gets closer to the present day, so the time span for segmentation has been adjusted to shorten it accordingly.

The themes of the chapters follow a chronological sequence: The Birth of Humanity (7 million years BC-130,000 years BC), The Last Ice Age (130,000-12,000 years BC), The Neolithic Age (12,000-4,000 years BC), The Copper and Bronze Ages (4,000-1,000 years BC), The Iron Age (1,000-600 years BC), Achaemenid Persia (600-200 years BC), Rome and the Han Dynasty (200 BC-100 AD), The Great Migration (200-600 AD), Islam and the Tang Dynasty (600-1000 AD), The Mongol Empire (1000-1400 AD), The Age of Exploration and Colonization (1400-1800 AD), and The 19th and 20th centuries (1800-2000 AD).

Then each theme is further divided into four sub-themes, with 48 panels in total. The overall structure of the world map is such that the various movements that occurred at the same time are represented on the world map, making it easy to move the viewer's gaze between the whole and its parts, stimulating new ideas on a meta-level. The explanations of each panel are mainly based on the narrative of the explanatory text and, in addition to the maps, chronological tables and photographs are also used to display visual information. Because the historical flow is an explanation of relationships, it is a hypothetical narrative but, through graphical representation, it gives the impression of an objective fact. For example, in the first section of the book, there is a graphic showing the birth of human beings and, since it begins with proto humans, the time axis starts 6 million years ago. These are hypotheses, just like the theory of continental drift, but they certainly stimulate the imagination.

In the world map, symbols and types of information can be seen in the legend and the frequent use of arrows in the symbolic expressions is a major feature.

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Arrows are indispensable for historical representation because they indicate changes over time. The thick lines indicate different types of areas, and the different colours indicate different attributes. These provide a hypothetical logical abduction, but it should be noted that this abduction is only possible through visual representation.

The index at the end of the book, which contains more than 5,000 entries of names of places and people, and combines keywords with historical locations (pages), can be referred to, indicating the spatial expansion and direction of development through maps. This is a history book and so the flow of the whole, and each theory, is developed by hypothetical reasoning. However, by showing the coordinate axes of time and space, the development of the story is clarified through visual images.

4. Visual perception and Abduction

Through the four sources, we have examined how Bertin has been involved with abductive reasoning. If we recapitulate this as a schematic of exploration, abduction, and heuristics from the traditional flow of communication in a diagram such as Figure 1, it can be summarized in Figure 2.

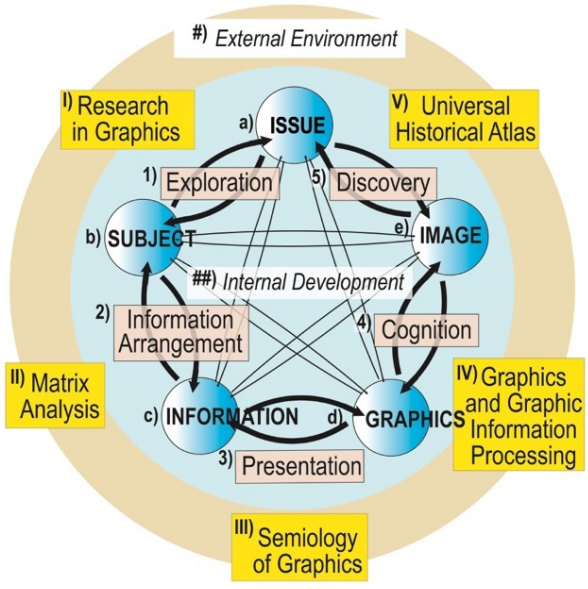

Figure 2. Cartographic development of imagination based on exploration, abduction, and heuristics

In Figure 1, the four stages of communication are positioned at the four vertices. In Figure 2, the a) issue and b) subject at the top of Figure 1 are independent of each other and become five stages a) ~e) in total (Figure 2-1). Exploration has been added to the logical transition connecting each vertex and shown as five connections: 1) exploration, 2) information arrangement, 3) presentation, 4) cognition, and 5) discovery. The transitions are indicated by two-way arrows, forward and reverse, indicating a process of dynamic abductive reasoning and trial-and-error. The process is also connected diagonally, as it can occur in the interrelationship of adjacent parts, as well as between opposite stages (Figure 2-2). When we look at these things from a broader perspective, we can see that there is #) an external environment and, within that environment, there is the development of ##) internal graphic thinking (Figure 2-3), which was revealed by Bertin's theories I) ~V).

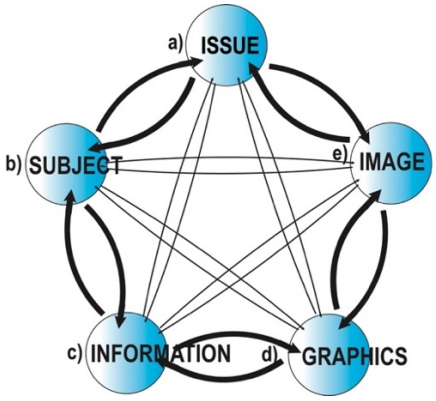

Figure 2-1 Five stages of different tasks

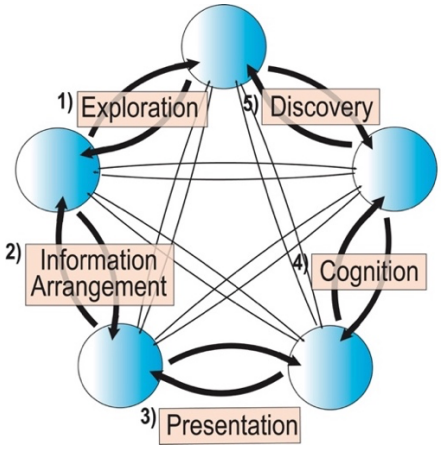

Figure 2-2 Five development actions

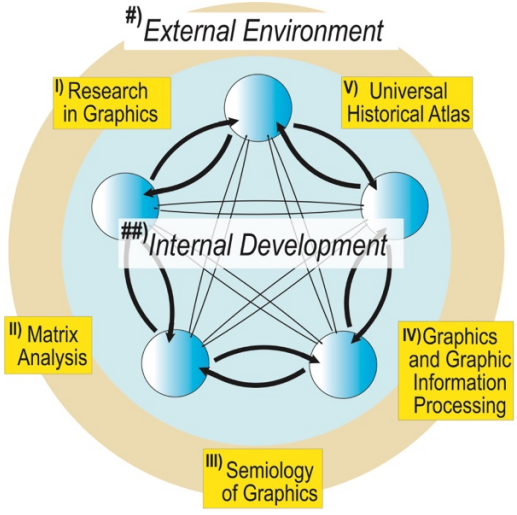

Figure 2-3 External environment and internal development

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Of these, the method of Matrix Analysis is II) is not a separate book, but the method of orderable matrix, which is part of Bertin's method, is a major feature, and as we have seen, methods using matrices are applied extensively, from matrix analysis of issues to the basic framework of the World History Atlas.

This diagram, of the cartographic development of imagination, shows that understanding and discovering relationships of distributed cartographic signs is essentially a method of dynamic abductive reasoning 1) ~5), given that the graphic representation is a visual representation of the relationships between the components and leads to new discoveries.

In "Research in Graphics" (1952), Bertin oversaw the graphics part of the research projects conducted by various researchers, first examining the methods used for each research purpose. As a result of collecting these methods, commonalities were found, in terms of the methods used and the process of theorizing them, as "research in graphics" was adopted. The focus is on cartographic presentation, organizing the correspondence between objectives and symbolic presentation, but it also includes elements of Figure 2 because it refers to the reasons why graphic representation is useful in collaborative research, where researchers may have common visual images, common abductive images for the next step, and a final common image of discovery. In Bertin, this means that, from an early stage, it also included elements of "exploration, the development of abductive reasoning and discovery".

The next development, "Semiology of Graphics," is organized around graphic representation but it shows how each of the categorized methods of representation is organized as a sign system and how the effects differ in their operation. It discusses the selection of methods that yield better results for the purpose. The discussion is about the choice of the method that will yield the best results for the chosen objectives. In essence, the choice of method is abductive, and the operation of a visual matrix is a typically abductive method.

Furthermore, in "Graphics and Graphic Information Processing", the process begins with setting objectives and arranging information, and then proceeds to the graphic presentation of information, generating comprehensible structures and patterns through symbols, and assigning meaning to them. All of this involves a process of trial and error and are hypothetical reasoning processes; therefore, they are abductive operations.

The last book, the "Universal Historical Atlas," is a time series atlas. The first section is a visualization of history, assembled in a visual matrix of time and space, which provides a structure in which the whole and its parts can be viewed simultaneously, allowing the viewer to graphically image trends from both macro and micro perspectives. These images are both a hypothesis and an inference of history through the visual, the system itself is abductive.

What is the relationship between these ideas and the basic concepts that characterize cartography: exaggeration, omission, superimposition, juxtaposition, rotation, scale selection, projection selection, symbolic transformation, etc.? It can be seen that all of these are derived because of operations involving dynamic trial and error, which are abductive in nature. The key is whether there is agreement in the expressions because there are both good and bad, even if they have so-called ‘originality’. On the other hand, it is also known that there are individual differences in vision from a psycho-physical point of view, such as visual illusions and three-dimensional grasping. Therefore, the basic concepts of map representation should enable everyone to be able to feel the sense of discovery and development instead of a simple act of verification. Furthermore, these concepts may have the potential to expand into themes such as the discipline of cartography (Palsky, 2013), design thinking (Renon, 2020), and theoretical cartography and ubiquitous mapping (Morita, 2022).

5. Conclusion

Although Bertin seems to have proposed a method involving a monosemic visual system, in fact, as we have seen, a method which stimulates vivid abductive reasoning through graphics is central to his interests. He should be seen as having pursued a theoretical framework, such as visual variables, to effectively advance his ultimate method of graphic thinking.

Therefore, the conventional communication theory view of clarity in graphic representation must be reconsidered as a framework for the dynamic, logical development of graphics as a method of "exploration, abduction, and heuristics". These dynamic processes may easily be followed in today's digital information systems, but many of them have merely become automatic data display systems. To create a hypothesis-discovery reflective process, it is essential to create a step-by-step system that can be operated by oneself. To this end, it is necessary to have a system that records the process of trial and error, or in other words, the process of contrasting alternative views of progress and regression and conducting the development of a further advanced image. We look forward to further developments in this direction.

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