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Concept of the Second Cybernetics Influences all Areas of Scientific Knowledge: Scientometric Study from 1963 to 2021

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Abstract: ***The concept of the Second Cybernetics, exhibit in 1963 by Magoroh Maruyama, proposed a different way of evaluating the relationship between the variables existing in a system, postulating that there is a permanent imbalance between them, opposing the "first" cybernetics of static equilibrium, therefore, the relevance of this study is to demonstrate that the paradigm of contemporary information science has the aforementioned concept in its epistemology. This scientometric research analyzed to what extent the Second Cybernetics permeates contemporary science, through the identification of scientific publications that use it as a reference. Data were obtained from the Web of Science, SCOPUS and JSTOR databases, considering the years 1963 to 2021. The compilation of this corpus was carried out using the Bibliometrix software version 4.0.0 and the collection and extraction was carried out directly with resources available in the indicated databases. The results of the study showed that the concept of the Second Cybernetics is referenced in 980 articles, generating influence in the scientific environment with new publications every year; indexed articles in the areas of Social Sciences and Human Sciences account for 69.1% of the research carried out under this influence; the concept is present in all eight areas of knowledge defined by Coordination for the Improvement of Higher Education Personnel (CAPES).***

Keywords: Scientometrics, Bibliometrics, Second Cybernetics, Information Science, Epistemology

1. Introduction

The relevance of this study lies in demonstrating that the paradigm of contemporary information science (IS) has in its epistemology the founding concept of Second Cybernetics. This scientometric study demonstrates this relevance through an analysis of the extent to which that concept pervades the field of IS today. The research also demonstrates how it is consistent with that of IS in terms of information use.

The article entitled "The Second Cybernetics: Deviation-amplifying Mutual Causal Processes" [1] presented the seminal concept of the Second Cybernetics and was the starting point of this scientometric study that seeks to identify its appropriation and use in other areas of knowledge. In this article, the author describes the theory of increased heterogeneity in the value of variables in causal loops. In the original concept of Second Cybernetics, Maruyama explains that:

> The deviation-counteracting mutual causal systems and the deviation-amplifying mutual causal systems may appear to be opposite types of systems. But they have one essential feature in common: they are both mutual causal systems, i.e., the elements within a system influence each other either simultaneously or alternatingly. The difference between the two types of systems is that the deviation-counteracting system has mutual negative feedbacks between the elements in it while the deviation-amplifying system has mutual positive feedbacks between the elements in it [1].

That is, systems in which the variables neutralize their deviation have a relationship in which increasing the value of one variable decreases the value of another, whereas systems in which the variables amplify their deviation have a relationship in which increasing the value of one variable increases the value of another.

This seminal concept has a ubiquitous characteristic, that is, it makes it possible to explain how the dynamics involving components of systems that feedback are present everywhere, allowing to explain, for example, natural events such as the germination of a seed, the behavior of the schizophrenic individual, the birth and growth of a mammal; social events such as the economic system in a country, the relationship between education and economic growth, or the functioning of a farmers' cooperative; as well as artificial events such as a computer system, the production of electrical energy in a nuclear power plant or the directing of a spacecraft to the outer reaches of the Solar System [2–7].

Precisely because it is versatile, Maruyama's proposal is widely applied from information systems to industry, commerce, and the economy [8]; in studies of behavioral psychology, consumption habits, and interpersonal relationships [9]; in computerized systems such as automation and control [10] used to maintain the stock level in businesses of all sizes, including the production level in industries, investment portfolios in stock brokerages, the distribution of the flow of means of road, fluvial, sea, and air transport, and, more recently, in the control of satellites and orbital stations [11]; and That is, systems in which it is necessary to permanently evaluate the behavior of the value of variables that present some kind of relationship among

themselves in what is called "pervasive information architecture."

The postulate of the Second Cybernetics also demonstrates that in complex systems, such as the human body, it is not necessary for all the information that describes it to be stored and available in the genes that define it [1].

> […] it is not necessary for the genes to carry all the information regarding the adult structure, but it suffices for the genes to carry a set of rules to generate the information [1].

In the literature review carried out by Camboim et al. [11] about the existing relationships between the pervasive information architecture and the heuristics applied in the design of information systems based on it, the authors point out that:

> [...] information architectures become ecosystems; users become intermediaries; the static becomes dynamic; the dynamic becomes hybrid; the horizontal prevails over the vertical; product design becomes experience design; experiences become "between" experiences.[11].

In other words, in an information system, the idea of the Second Cybernetics is present as a condition for its full functioning. The pervasive information architecture, in particular, allows inference that Second Cybernetics is consolidated as adequate to model contemporary systemic solutions. To exemplify, a library with a million titles does not require the user to have all the information on the full content of all these books to be able to find one that deals with a specific theme, that is, by a specific author or publisher; it is enough that he knows the rules governing the organization of the collection, and it will be possible to find a given book, regardless of knowing its contents.

The objective of this work was to identify the extent to which the Second Cybernetics, proposed by Maruyama [1], in the context of interdisciplinary science [12], influences research in the eight areas of knowledge defined by the Coordination for the Improvement of Higher Education Personnel (CAPES): Applied Social Sciences, Human Sciences, Exact and Earth Sciences, Health Sciences, Engineering, Biological Sciences, Agricultural Sciences, Linguistics and Arts [13]. This is demonstrated through the application of the techniques presented in Section 2: Literature Survey. The method applied to carry out the research is detailed and described in Section 3: Methodology. The Section 4: Results and Discussion, presents the indicators obtained in this scientometric study. In Section 5: Conclusion, a reflection is made on the journey of this research, given the limitations imposed by some indexing bases and what the future may hold.

The number of citations of Maruyama's 1963 article was used as a quantitative indicator in order to verify the evolution of references to the initial proposal of the Second Cybernetics as well as its recurrence over time in the scientific production published and indexed in the databases consulted.

2. Literature Survey

2.1 Scientometrics from a theoretical and technical perspective

Scientometrics can be defined as the study of measuring and quantifying scientific progress, for which bibliometric indicators are used, and have become a popular discipline as a set of methods for analyzing the sociology of science [14–16].

It is a field of investigation that engages research in various areas of knowledge, namely: history, philosophy, sociology, economics, psychology, mathematics, engineering, biology, and medicine. Scientometrics has also piqued the interest of administrators of governmental and non-governmental organizations who use this method to support policy definitions for science [17, 18].

The scientometric approach can also contribute to a quantitative assessment of science due to the possibility of drawing parallels between activities in a given period, including productivity and progress in the areas of study, substantially helping those responsible for planning the use of financial resources and manpower available so that they can be applied more efficiently. Sengupta [17] argues that one of the objectives of scientometrics is to measure the organizational and management aspects of science in a country.

Among the structural aspects of scientometrics, the thinking of Dobrov apud Sengupta [17] is one:

> [...] greater emphasis on a longer historical past that is associated with scientometric work in the analysis of informational parameters of the development of science, such as the number of articles, patents, journals, laws of aging and dissipation of scientific information, structure of the flow of scientific documents, citation processes, etc. [17].

According to Oliveira [19], there are two large groups of indicators. The "basics of production," constituted by counting the number of publications by the researcher, group of researchers, institution, or country, reflect the impact on the scientific community to which they belong. And there are "link" indicators, based on the co-occurrence of authorship, quotes, or words, and used for mapping and building collaboration networks.

Many of the indicators used in Metric Studies of Information (MSI) for planning, evaluation, and management in Science, Technology, and Innovation (ST&I) measure some specificity of scientific production or the occurrence of scientific communication. [20], [21], [22], and [23].

Among the articles and books considered for this research that deal with the MSI theme are Gouveia [24], Pinto [22], Curty & Delbianco [20], and Vanti [23]. It is observed that these authors adopt, in their works, the representation of the overlapping of the types of indicators and studies through the Venn diagram. This representation is a way to graphically demonstrate a set using a closed line (usually an

ellipse) that has no self-intersection. Inside these flat figures are the elements that make up the set. The Venn diagram was created to help people understand basic set operations like relation, inclusion, membership, union, intersection, difference, and complementary set [25].

Strictly speaking, according to discrete mathematics, in the representation of sets, the common elements that participate in an intersection and, therefore, overlap, must be exactly the same. As a result, if the representation used intersects two different types of MSI, the part that is common to both types must be exactly the same [25]. As shown in Figure 1, the result of the intersection of two sets A and B will be such that the elements participating in the intersection belong, obligatorily, to sets A and B—in this case, element g. Mathematically, we have: $A \cap B = \{x \mid x \in A \text{ and } x \in B\}$, which reads "A intersection B is equal to the set x, such that x belongs to the set A and x belongs to the set B". There are also elements that are unique to each set ("y" and "z" in the example).

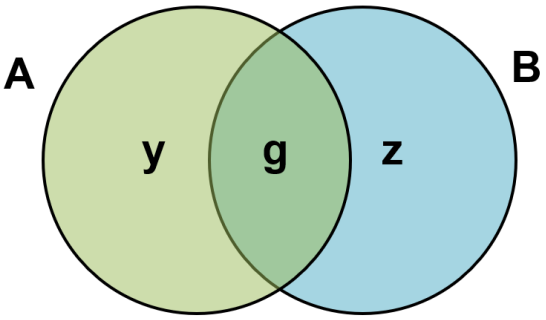

Figure 1: Venn diagram with intersection of two sets A and B.
Source: Adapted by the authors based on [25]

The different diagrams used to represent the MSI are discussed by Curty & Delbianco [20] as possibilities for visual models to approximate different subfields of study and research. The authors point out that each representation seeks to indicate what each subfield covers as MSI, and the areas that overlap in the diagrams, at least in theory, would cover exactly the same set of techniques applicable to each type of investigation.

Thus, if we consider the representation proposed by Gouveia [24], reproduced here in Figure 2, we can infer that the set formed by Informetrics encompasses the application of all known techniques and metrics within MSI. Scientometrics, in turn, encompasses almost all types of MSI. Therefore, it is understood that the representation through Venn diagrams is much more illustrative and conceptual than practical.

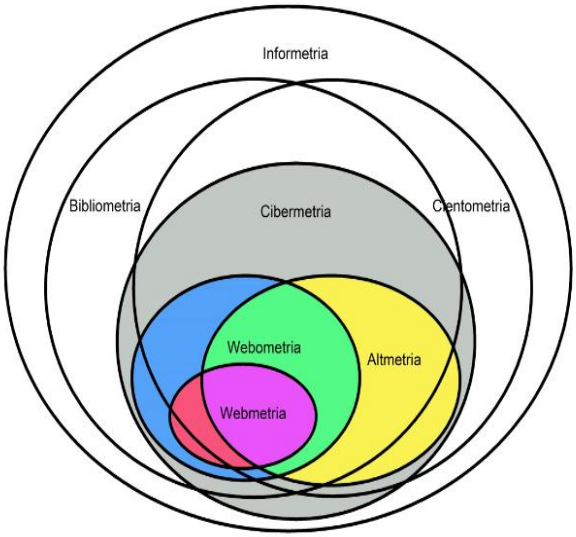

Figure 2: Diagram of relationships between fields
Source: [24]

From here, it is already possible to observe the influence of the Second Cybernetics on MSI. The representative diagrams of the union and intersection of the toolsets are not mathematically exact, but they demonstrate the variation of the research types to which these information analysis tools can be applied. That is, the rules that determine each technique, although they are clear, do not position them in this or that type of MSI but rather place them as complementary to each other.

Note, for example, the organization proposed by Bufrem and Prates [26], who expand the organization produced by McGrath [27] with a typology for classifying and defining the terms of each subfield. In the table that the authors proposed, there is a line with the typology or subfield in which the object of study is indicated for each term. When observing scientometrics, the chart informs that it focuses on the study of disciplines, subjects, scientific and technological fields, patents, dissertations, and theses, using variables such as the factors that differ in the subdisciplines and how scientists communicate, applying as methods the analysis of the correspondence set and the co-occurrence of terms, expressions, and keywords in order to achieve the objective of identifying the domains of interest and understanding the quantity and the way in which scientists communicate. Here, one can observe relationships between MSI and the Second Cybernetics when analyzing, in a systemic way, the three fundamental laws enunciated by the precursors of metric studies (Lotka, Bradford, and Zipf), which present relationships between variables such as: level of production of articles and number of citations; scientific journals and thematic concentration; and co-occurrence of words and area of concentration of a publication [28–30].

In this context, scientometrics occupies an important space in the analysis of the scientific communication process, as it helps to identify original productions and seminal theses and to understand how they advance their influence over time.

3. Methodology

According to Marconi & Lakatos [31], this work is classified as an exploratory study of a quantitative nature. It is a historical retrospective study based on scientific communications published between 1963 and 2021 that examines citations to Maruyama's seminal publication [1]. Thus, this research delineates what is actually indexed in the consulted databases and whose references to the article on the Second Cybernetics were indicated by their respective authors. The justification for choosing the Web of Science (WoS), SCOPUS, and JSTOR index databases is given below in this section, since the data files exported from the index databases and converted to the Bibliometrix 4.0 can be accessed through permanent links indicated in the appendices of this article and allow reproducing and exploring all 39 possibilities offered for analysis, which are not fully addressed here as they exceed the scope of the article.

The data selection strategies and some totalizers presented here in the methodology section reveal some important indicators, among them the h-index and total citations, which will receive more attention later in the Results & Discussion section. The author's name, Magoroh Maruyama, was considered a search keyword in the chosen indexing database, confirming its direct relationship with the article entitled "The Second Cybernetics: Deviation-amplifying Mutual Causal Processes."

In the SCOPUS indexing base, the search strategy requires the inclusion of the author's different AU-IDs because, in this base, his production is linked to the universities and institutes in which he worked [32], therefore the expression: AU-ID was used ("Maruyama, Magoroh" 7201927640) OR AU-ID("Maruyama, Magoroh" 56257325500) OR AU-ID("Maruyama, Magoroh" 56257326500) OR AU-ID("Maruyama, Magoroh" 57225324583) OR AU-ID(" Maruyama, Magoroh" 24783886000) OR AU-ID ("Maruyama, Magoroh" 56947082200) OR AU-ID ("Maruyama, Magoroh" 57066203800) OR AU-ID ("Maruyama, Magoroh" 57209539762) OR AU-ID ("Maruyama, Magoroh" 57226148802). On this basis, the reference to the article targeted by this study focuses not on the original article but on its insertion as a book chapter by Walter Buckley [33].

The WoS index base allows the application of two search strategies [34]. In the first, 20 indexed articles are obtained, which are authored by Maruyama. In the second, the search strategy employed was the title of the article, which, through the resources of this indexing base, used the expression: TS="Second Cybernetics: Deviation-amplifying Mutual Causal" obtaining 580 publications that cite the article of the Second Cybernetics.

In the JSTOR indexing base, the resource offered is the Constellate platform, provided by Portico and JSTOR, which offers indicators directly in addition to generating the exportable data set [35]. Here, the search strategy adopted was the title of the article "Second Cybernetics: Deviation-amplifying Mutual Causal Processes," which returned 360 articles whose reference appears as a direct citation.

Table 1 summarizes the initial data of the proposed scientometric study and presents the author's production level relative to his h-index in each of the databases consulted.

Table 1: Author Magoroh Maruyama's production indexes

Index base	Author-indexed articles	Author's h-index	Total citations by the author	Quotes from the Second Cybernetics article
SCOPUS	90	15	1195	30
WoS	20	7	728	580
JSTOR	36	Not provided	Not provided	360

Source: Adapted by the authors based on data obtained from the databases (2022)

The organization of the method for carrying out this research was based on an analysis of how other researchers conducted scientometric studies. A series of common steps were identified in Araújo [36], Pereira and Fujino [37], Maia and Caregnato [38], Fujino and Silva [39], Ivancheva [18], Kanagavel [40], and Kurian [41]. This resulted in seven steps, described in Chart 1, that were adopted to sequence the tasks necessary to carry out the present study.

Chart 1: Steps of the method adopted to carry out this scientometric study

Stage	Goal	Attention points
1	Define the theme and objective of the study and the candidate keywords to be applied in the search strategy in the indexing databases.	At this stage, the keywords are still candidates, as they will be tested in Stage 3.
2	Define the index bases where the necessary data will be collected.	Describe the primary objective of the chosen database and how it collaborates with the study.
3	Create the search strategy using candidate keywords and apply it to data collection. At this stage, it is common to carry out some tests with different strategies according to the objective defined in the study and adapt them to the particularities of each indexing base.	Boolean operators (AND, OR, NOR), indication of date restrictions (to place the collection period in time), and the choice of which fields will be considered in the search, such as author, title, abstract, full text, and references.
4	Record the process used for data collection and selection (filtering).	Indicate which steps were followed and the results obtained in each one.
5	Perform the processing of the collected data according to the objective of the study.	There is software available, such as Dataview, Excel, EndNote, Word, VOS viewer, and Bibliometrix, in addition to the resources offered by the indexing bases themselves.
6	Prepare the demonstration of the processed data through tables, graphs, diagrams, images, and other visual	The visual quality should be a concern for those who research. If the data cannot be read, it cannot be interpreted.

	strategies.	
7	The presentation and analysis of the data processed in the study must be carried out with great care.	Those who research should remember that the reading of the study can be done by someone who is not in their area of knowledge.

Source: Adapted by the authors of the works by Araújo [36], Pereira and Fujino [37], Maia and Caregnato [38], Fujino and Silva [39], Ivancheva [18], Kanagavel [40], and Kurian [41].

The JSTOR, SCOPUS, and WoS databases were chosen because they represent the consolidation of journals that publish in the field of interdisciplinary study. JSTOR—Journal Storage—is a digital library for the intellectually curious that helps everyone discover, share, and connect valuable ideas [32]. SCOPUS is the largest database of abstracts and citations of peer-reviewed literature, including scientific journals, books, conference proceedings, and industry publications [42]. The Web of Science is the largest publisher-neutral citation index and research intelligence platform [43].

The data obtained, as indicated in Table 1, generated files that could be imported by Bibliometrix, except for JSTOR, whose analysis was performed directly on the Constellate platform. The graphics images were generated by Bibliometrix in PNG format and are available in high resolution through persistent links for online access, listed in Appendix 2.

In order to calculate the extent to which the influence of the Second Cybernetics occurs in the areas of knowledge, according to the classification of the eight CAPES areas, a data export was generated with the count of articles by category in the WoS index base. It was chosen because it had the highest number of citations in this study—580 in all. Each WoS category was empirically associated with the CAPES category based on this export.

This empirical step was necessary as, in the indexing base, the classification of the area to which each publication is linked is not provided with the export of raw data. However, the platform offers the option to export the total number of publications in each category.

4. Results & Discussion

The main objective of this article was to identify the extent to which the Second Cybernetics is present in contemporary science, demonstrating how its concepts are consistent with those of IS. In this sense, the method we adopted of identifying scientometric practices applied in other works on which to base this scientometric study (Chart 1) proved effective in organizing activities and highlighting the points of attention to obtain the best result.

The measurement of the influence of the Second Cybernetics in the areas of knowledge classified by CAPES, presented in Table 2 and represented in Figure 3, fulfills this objective by showing that all eight areas have indexed articles that make direct reference to the seminal article entitled "The Second Cybernetics: Deviation-amplifying Mutual Causal Processes" [1].

Table 2: Total articles by CAPES Area

Knowledge Area (CAPES)	Total productions	% in relation to the total (580)
6. Applied Social Sciences	207	35,7%
7. Human Sciences	194	33,4%
1. Exact and Earth Sciences	79	13,5%
3. Engineering	41	7,1%
2. Biological Sciences	32	5,5%
4. Health Sciences	22	3,8%
8. Linguistics and Arts	4	0,7%
5. Agricultural Sciences	1	0,2%
TOTAL	**580**	**100%**

Source: prepared by the authors

Figure 3 provides a relativized reading that can be useful from an instrumental standpoint when adding the percentages of occurrence of citations in areas 6 and 7: applied social sciences (35.7%) and human sciences (33.4%). Thus, 69.1% of citations appear in these two areas, indicating how much the Second Cybernetics permeates them.

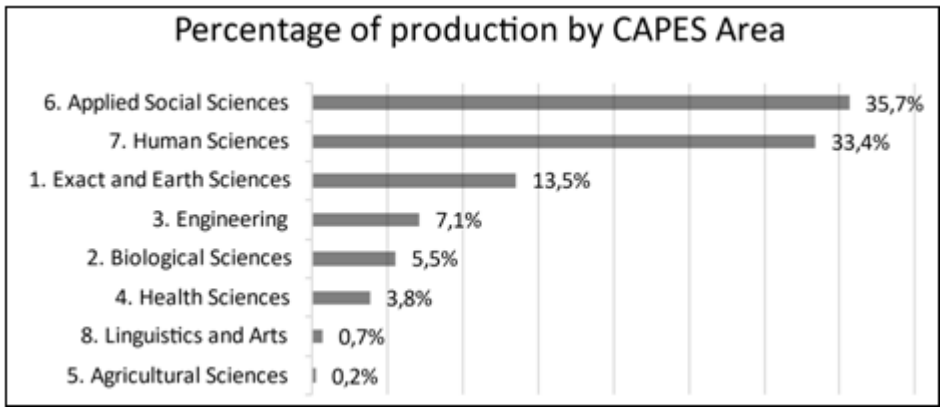

Figure 3: Relative total of articles classified by category in indexing databases
Source: Prepared by the authors based on WoS data.

The research undertaken and conducted by Magoroh Maruyama is present in some areas of study. In the analysis of the articles produced by the researcher, the statistical technique of factor analysis was applied to generate the map of conceptual structure with the MCA method (Multiple Correspondence Analysis), using bigrams [44], from the abstracts of the 90 articles contained in the indexing database SCOPUS, on which Maruyama is the lead author. The multiple correspondence analysis generated four clusters, showing, as shown in Figure 4, that their works focus on the following themes: 1) causal loops, 2) information theory, 3) heterogeneous systems, and 4) public management.

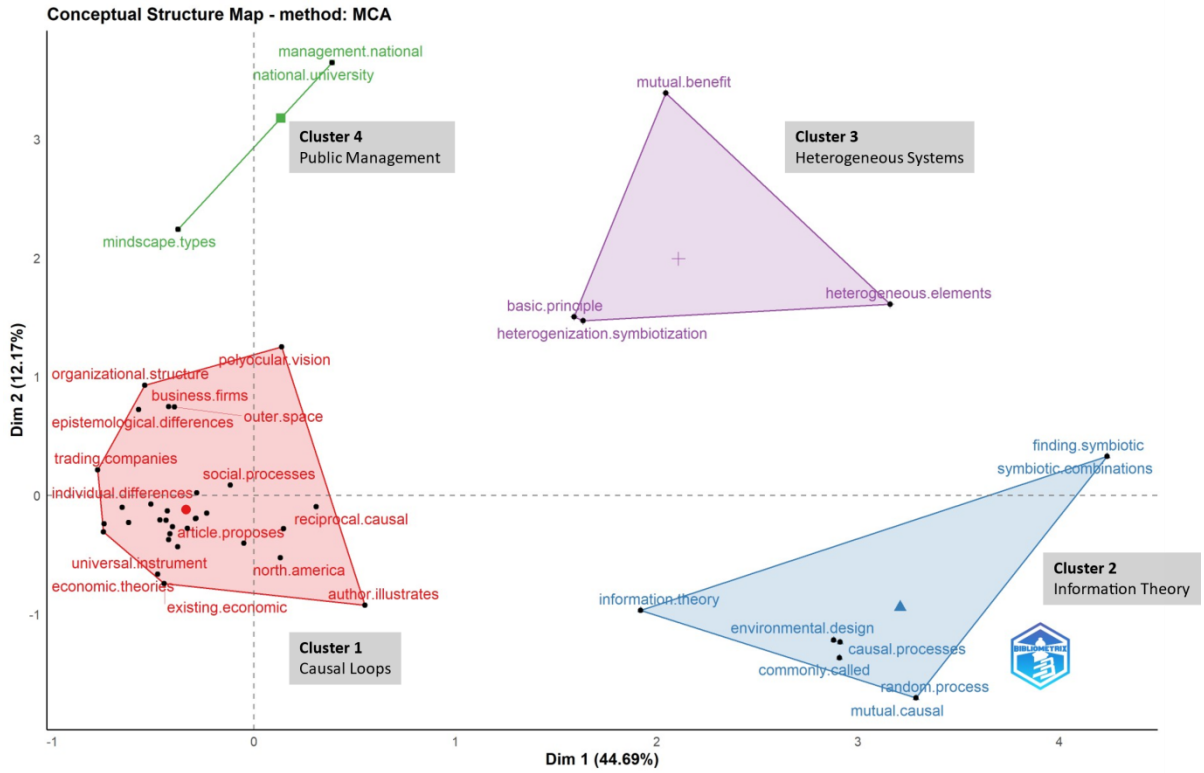

Figure 4: Conceptual Structure Map of Magoroh Maruyama's Works through the MCA Method, Generated in the Bibliography

Source: prepared by the authors based on SCOPUS data

This map is based on the count of the bigrams that make up the nominal categorical data, which are used to detect and represent the structures underlying this dataset; that is, it shows the bigrams that appear frequently in each article in which they appear [45]. In other words, Maruyama's areas of research are consistent with the application of Second Cybernetics in other fields of study. The concepts that are specifically consistent with IS are shown in Chart 2, and three of them are exemplified in this work.

Table 2: Second Cybernetics Concepts vs. Information Science Concepts

Concepts in the Second Cybernetics	Concepts in Information Science
Systems that neutralize or amplify the deviation of variable values have an essential feature in common: both are mutual causal systems, that is, the elements within a system influence each other simultaneously or alternately. The two types of systems have mutual negative or positive feedback between the elements contained therein [1].	The three fundamental laws enunciated by the precursors of metric studies (Lotka, Bradford, and Zipf) present relationships between variables such as level of production of articles and number of citations; scientific journals and thematic concentration; and co-occurrence of words and area of concentration of a publication [28–30].
The elements of a set are represented inside plane figures in a Venn diagram to aid understanding of basic set operations such as relation, inclusion, membership, union, intersection, difference, and complementary set [25].	The representative diagrams of the union and intersection of the MSI sets are not mathematically exact but demonstrate the variation of the types of study that can be applied to different techniques of analysis of the information within each type of study, according to the representation proposed by Gouveia [24] and reproduced in Figure 2 of this article.
In complex systems, such as the human body, for example, it is not necessary for all the information that describes it to be stored and available in the genes that define it; it is enough that they carry the set of rules to generate this information [1].	[...] information architectures become ecosystems; users become intermediaries; the static becomes dynamic; the dynamic becomes hybrid; the horizontal prevails over the vertical; product design becomes experience design; experiences become experiences "between" channels. [11].

Source: adapted by the authors through empirical analysis.

In view of this, there remains evidence that there is a relationship between the concepts of Second Cybernetics and IS. The discussion proposed here reinforces the importance of considering this relationship, given that, in the epistemology of science, the appropriation of concepts in an interdisciplinary way can benefit the fields of study involved by imbuing transit analytical and interpretation perspectives with innovative potential when they pass from a field scientist to another.

Raw data from articles indexed in WoS with direct citations to Second Cybernetics were imported and treated with the support of Bibliometrix, which allowed evaluating some complementary aspects of their relevance, especially in IS.

Table 3: Main information about the data and types of documents obtained in WoS

Description	Results
Period	1963-2021
Sources (magazines and books)	306
Documents	508
Mean age since publication (years)	30,1
Average citations per document	54,63
Total authors	625
Single-author documents	205
Types of Documents	
Articles	398
Procedure manual	35
Reviews	44
Books	12
Notes, Letters and Discussions	19

Source: Elaborated by the authors based on data compiled in the Bibliometrix.

Table 3 displays the key information from the WoS database documents. Of the total of 508 documents between 1963 and 2021 related to direct citations to Maruyama's article in the Second Cybernetics, an annual growth rate of around 1.91% is observed, and the average number of citations per document is 54.63.

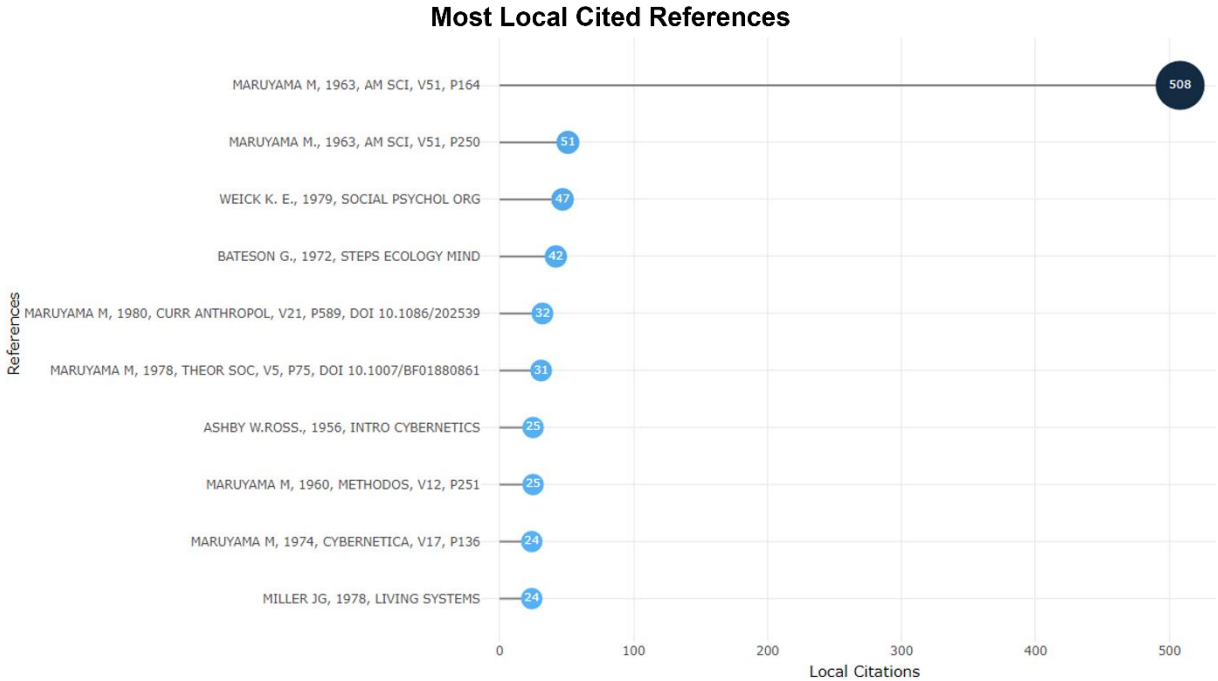

Figure 5: Graph depicting the ten most cited references in the works collected in WoS, bringing the citation count for the Second Cybernetics article to 508 citations.
Source: elaborated by the authors with bibliometrics based on WoS data.

Another finding in relation to publications on the theme of second cybernetics is their variability over time. Specifically, consistent growth was observed from the end of the 1960s through the 1980s. There was a later oscillation in the 1990s and a large drop in the early 2000s. Finally, there is growth in the 2010s and some decline in the early 2020s, as shown in Figure 6.

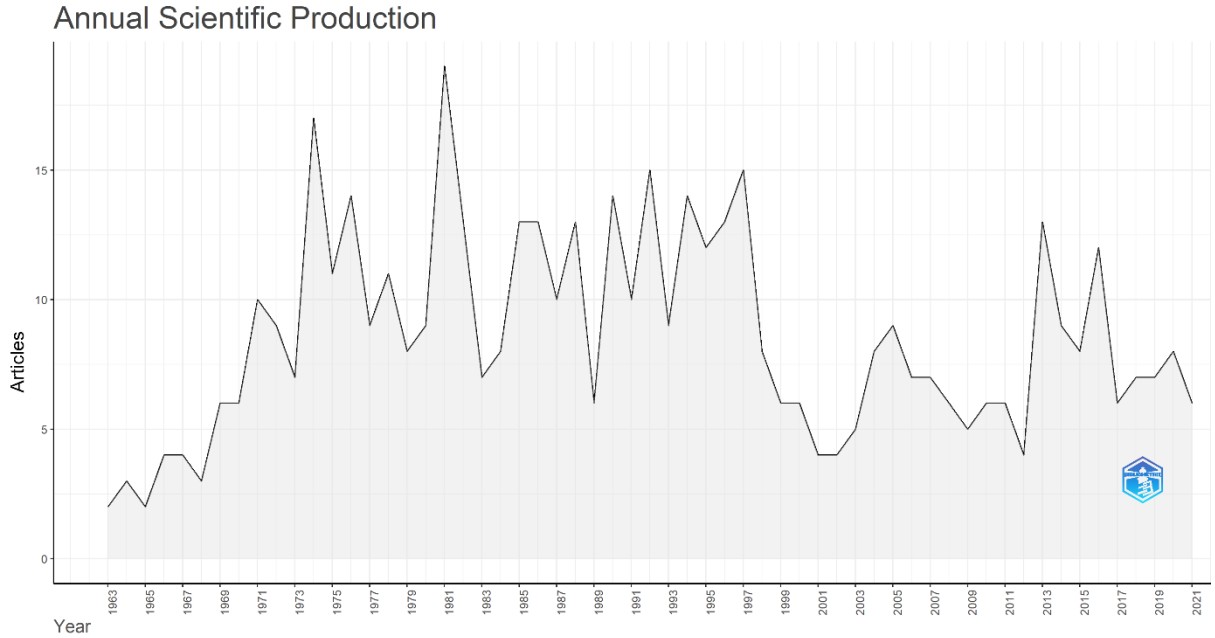

Figure 6: Production variability graph from 1963 to 2021 centered on the Second Cybernetics article.
Source: elaborated by the authors with Bibliometrix based on WoS data.

From an analytical cut of the data and considering the publications with direct citations in the last 15 years—between 2006 and 2020—and separating them into subsequent 5-year cycles, an increase in the average can be seen in relation to the immediately previous 5-year period. That is, between 2006 and 2010, the average was 6.2 citations per year; between 2011 and 2015, the average was 8,0, and between 2016 and 2020, it was 8.8 citations per year (Figure 7).

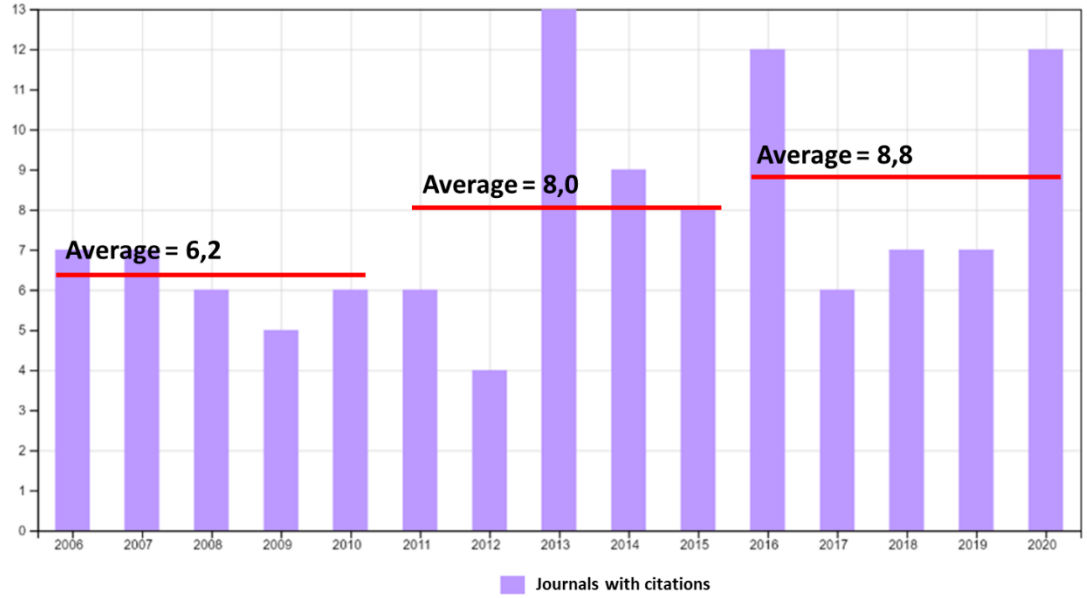

Figure 7: Number of publications with citations per year (2006-2020)
Source: Adapted by the authors from Web of Science [43].

Although there is oscillation in the first decades after publication and decreases in citations between the end of the 1990s and the beginning of the 2000s, in the last 15 years the variation in average citations with a tendency to increase is consistent, indicating a resumption of discussions around the theme as well as its influence on the analysis of complex systems.

5. Conclusion

Maruyama's Second Cybernetics Thesis has influenced researchers since its publication in 1963. During this work, influences were also identified in patents, books, essays, congresses, and the orientation of public policies in several nations, which were not addressed but may be the subject of future studies.

It was demonstrated that Maruyama's thesis permeates, in different ways, all areas of knowledge, with an emphasis on applied social sciences and humanities, which together represented 69.1% of indexed publications. This shows how important the Second Cybernetics is for research that tries to figure out how variables and parts of systems work.

To carry out this scientometric study, steps were compiled based on the practices recorded by other researchers in their own published scientometric studies. The method used to write this article, which was based on this compilation, can be tweaked and improved. Its structure and format may also be changed by the different tools that databases and raw data analysis systems, like Bibliometrix, offer.

To figure out how many citations were found and which area of knowledge each one belonged to, it was important to find a way to group and add up the data, even though the raw data file didn't have a field that said which area each publication belonged to. However, WoS allows obtaining the total number of publications by area; that is, even without knowing which area each publication is related to, it is possible to know how many publications are from a certain area. Thus, it was possible to state "to what extent" the thesis of the Second Cybernetics influences the areas of knowledge.

Considering the importance that scientometric studies have assumed in all areas, especially with regard to understanding the sociology of science, its types of epistemological relationships, and its collaboration and production networks, it is worth looking at the Second Cybernetics as an ally to see analyses of the development process of science as a development of society. It is also worth noting that if you take advantage of the fundamental assumptions of a field of study without looking at them critically, you may miss out on opportunities to advance.

The evolution of electronic computing and IS, with the support of cybernetics and the construction of measurement and simulation instruments, makes these fields increasingly sophisticated and interactive. Future research could focus on the impact of scientific production on Second Cybernetics in these two fields in particular.

6. Future Scope

Future research could also focus on the impact of Maruyama's Second Cybernetics Thesis on specific industries and businesses, such as education, healthcare, and technology. Another area of interest could be studying the role of cybernetics in decision-making and how it can be applied to improve organizational performance. Additionally, the use of cybernetics in the development of artificial intelligence and machine learning could also be explored.

- Investigating the impact of Maruyama's Second Cybernetics Thesis on the development of measurement and simulation instruments in the field of electronic computing and IS.
- Examining the relationship between Maruyama's Second Cybernetics Thesis and the evolution of public policies in various nations.
- Analyzing the influence of Maruyama's Second Cybernetics Thesis on the collaboration and production networks within the sociology of science.

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Author Profile

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Appendix

8.1 Appendix 1: Table of WoS Categories and CAPES Areas

Table 4: Table of database categories x CAPES categories

Web of Science categories	Total	CAPES Area
Management	78	6. Ciências Sociais Aplicadas
Business	59	6. Ciências Sociais Aplicadas
Computer Science Cybernetics	49	1. Ciências Exatas e da Terra
Social Sciences Interdisciplinary	44	6. Ciências Sociais Aplicadas
Regional Urban Planning	43	6. Ciências Sociais Aplicadas
Ergonomics	37	3. Engenharias
Psychology Multidisciplinary	32	7. Ciências Humanas
Psychology Clinical	28	7. Ciências Humanas
Anthropology	24	7. Ciências Humanas
Economics	23	6. Ciências Sociais Aplicadas
Family Studies	23	7. Ciências Humanas
Sociology	23	7. Ciências Humanas
Geography	21	7. Ciências Humanas
Psychology	19	7. Ciências Humanas
Computer Science Information Systems	17	1. Ciências Exatas e da Terra
Information Science Library Science	17	6. Ciências Sociais Aplicadas
Operations Research Management Science	16	6. Ciências Sociais Aplicadas
Environmental Studies	15	7. Ciências Humanas
Psychiatry	15	4. Ciências da Saúde
Psychology Social	13	7. Ciências Humanas
Political Science	12	7. Ciências Humanas
Psychology Applied	12	7. Ciências Humanas
Engineering Electrical Electronic	11	3. Engenharias
Public Environmental Occupational Health	11	7. Ciências Humanas
Computer Science Interdisciplinary Applications	10	1. Ciências Exatas e da Terra
Multidisciplinary Sciences	10	6. Ciências Sociais Aplicadas
Computer Science Theory Methods	9	1. Ciências Exatas e da Terra
Neurosciences	9	2. Ciências Biológicas
Biology	8	2. Ciências Biológicas
Ecology	8	2. Ciências Biológicas
Psychology Biological	8	7. Ciências Humanas
Social Work	8	6. Ciências Sociais Aplicadas
Urban Studies	8	1. Ciências Exatas e da Terra
Archaeology	7	6. Ciências Sociais Aplicadas
Education Educational Research	7	7. Ciências Humanas
Psychology Developmental	7	7. Ciências Humanas
Computer Science Artificial Intelligence	6	1. Ciências Exatas e da Terra
Environmental Sciences	6	2. Ciências Biológicas
Public Administration	6	6. Ciências Sociais Aplicadas
Automation Control Systems	5	3. Engenharias
Engineering Industrial	5	3. Engenharias
International Relations	5	7. Ciências Humanas
Philosophy	5	7. Ciências Humanas
Psychology Experimental	5	7. Ciências Humanas
Communication	4	8. Linguística, Letras e Artes
Gerontology	4	4. Ciências da Saúde
Mathematical Computational Biology	4	1. Ciências Exatas e da Terra
Social Issues	4	7. Ciências Humanas
Development Studies	3	7. Ciências Humanas
History Philosophy Of Science	3	7. Ciências Humanas
Medicine General Internal	3	4. Ciências da Saúde
Plant Sciences	3	2. Ciências Biológicas
Psychology Educational	3	7. Ciências Humanas
Substance Abuse	3	4. Ciências da Saúde
Chemistry Multidisciplinary	2	1. Ciências Exatas e da Terra
Computer Science Software Engineering	2	1. Ciências Exatas e da Terra
Developmental Biology	2	2. Ciências Biológicas
Engineering Manufacturing	2	3. Engenharias
Evolutionary Biology	2	2. Ciências Biológicas
Forestry	2	5. Ciências Agrárias
Geriatrics Gerontology	2	4. Ciências da Saúde
Humanities Multidisciplinary	2	7. Ciências Humanas
Law	2	7. Ciências Humanas
Mathematics Applied	2	1. Ciências Exatas e da Terra
Mathematics Interdisciplinary Applications	2	1. Ciências Exatas e da Terra
Medicine Research Experimental	2	4. Ciências da Saúde
Microbiology	2	2. Ciências Biológicas
Psychology Mathematical	2	7. Ciências Humanas
Social Sciences Mathematical Methods	2	6. Ciências Sociais Aplicadas
Zoology	2	2. Ciências Biológicas
Andrology	1	4. Ciências da Saúde
Area Studies	1	2. Ciências Biológicas
Behavioral Sciences	1	7. Ciências Humanas
Biochemistry Molecular Biology	1	2. Ciências Biológicas
Business Finance	1	6. Ciências Sociais Aplicadas
Cell Biology	1	2. Ciências Biológicas
Chemistry Physical	1	1. Ciências Exatas e da Terra
Clinical Neurology	1	4. Ciências da Saúde
Criminology Penology	1	7. Ciências Humanas
Demography	1	6. Ciências Sociais Aplicadas
Dentistry Oral Surgery Medicine	1	4. Ciências da Saúde
Education Scientific Disciplines	1	7. Ciências Humanas
Engineering Environmental	1	3. Engenharias
Entomology	1	2. Ciências Biológicas
Ethics	1	7. Ciências Humanas
Film Radio Television	1	6. Ciências Sociais Aplicadas
Folklore	1	7. Ciências Humanas
Geography Physical	1	7. Ciências Humanas
Geosciences Multidisciplinary	1	1. Ciências Exatas e da Terra
Health Policy Services	1	4. Ciências da Saúde
Language Linguistics	1	8. Linguística, Letras e Artes
Marine Freshwater Biology	1	2. Ciências Biológicas
Meteorology Atmospheric Sciences	1	1. Ciências Exatas e da Terra
Music	1	8. Linguística, Letras e Artes
Pediatrics	1	4. Ciências da Saúde
Physics Applied	1	1. Ciências Exatas e da Terra
Physics Atomic Molecular Chemical	1	1. Ciências Exatas e da Terra
Physics Fluids Plasmas	1	1. Ciências Exatas e da Terra
Physics Mathematical	1	1. Ciências Exatas e da Terra
Physics Multidisciplinary	1	1. Ciências Exatas e da Terra
Physiology	1	2. Ciências Biológicas
Religion	1	7. Ciências Humanas
Reproductive Biology	1	2. Ciências Biológicas
Sport Sciences	1	3. Engenharias
Telecommunications	1	1. Ciências Exatas e da Terra
Water Resources	1	3. Engenharias

Source: Authors based on WoS data.

8.2 Appendix 2: Permalink list with raw data

https://drive.google.com/drive/folders/1Sh7koRZOokSFbNjGoXoGzuXUPkDElWAc?usp=sharing