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Bibliometric study about chaotic cryptography in developing countries

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Abstract—In this paper, an analyse of scientific journal articles related to chaotic cryptography from 2015 to 2021, is presented. In doing so, the study uses the Web of Science Core Collection database to analyze the data. ‘biblioshiny’ a web-interface of the ‘bibliometrix 3.0’ package of R-studio has been deployed to conduct bibliometric analysis. Also, a graphical mapping of the bibliometric material by using the visualization of similarities (VOS) viewer software, was developed. The study relies on the proposed approach to explore the influence of developing countries on Chaos-based encryption. We found out that developing countries are the most active on chaotic cryptography.

Keywords—Bibliometrics, Chaotic Cryptography, R-studio, Web of Science, VOS viewer.

I. INTRODUCTION

Chaos is an important phenomenon in nonlinear systems which has been intensively studied in the last decades and used in many commercial applications [1]–[3]. Chaos-based cryptographic are used as an alternative to classical cryptographic primitives for data security. Indeed, this is because of the fact that there is intrinsic randomness in chaotic signals and ease of designing robust chaos based cryptographic primitives. Whose first issue was published in 1989 by Robert Matthews [4]. Ben Slimane *et al.* [5] proposed a fast and secure scheme for image encryption using the nested chaotic maps and the DNA sequence operation. They also designed an efficient image cryptosystem [6] using a single neuron model, a chaotic map and DNA sequence operations. Puteaux and Puech [7] put forward a new reversible data hiding method in encrypted images based on an adaptive local Shannon entropy analysis. They also suggested [8] an efficient method of reversible data hiding in encrypted images based on most-significant-bit prediction with a very high embedding capacity. They described an efficient method [9] of noisy encrypted image correction relying on a new (Cipher-Feedback then Electronic-Code-Book-mode-based) image encryption technique. In 3D objects encryption, Jansen van Rensburg *et al.* proposed an

homomorphic two tier reversible data hiding in encrypted 3D objects [10].

Cryptanalysts try to break secret code by using different methods like Brute Force attack, Linear Cryptanalysis, differential cryptanalysis and others. Cryptography is an art to be written in coded language [11]. It can provide a better and fast security for multimedia applications and for images particularly [12].

Motivated by the modelling and the generation of the new chaotic systems, like the generation of multi-scroll chaotic attractors by Bouallegue [13], also his work named Chaotic attractors with separated scrolls [14], then Gallery of chaotic attractors generated by fractal network [15], also he has a research named A new class of neural networks and its application [16], this class was developed for chaotic systems. All those systems can be used for encryption. It comes out that there is no bibliometric study discussed chaotic cryptography in particularly. Bibliometrics is an important tool for assessing and analysing the published scientific literature from a quantitative perspective. In recent years, a wide range of bibliometric studies have developed covering journals, topics, countries, and institutions [17]. The studies focused on journals include Strategic Management Journal [18], Knowledge-Based Systems [19], Computers and Industrial Engineering [20], European Journal of Operational Research [21] and Information Sciences [22]. Regarding topics, it is worth mentioning some key areas, including computational intelligence [23], fuzzy research [24], [25], data mining [26] and operations research and management science [27]. Additionally, there are also several studies that have focused on countries [28], [29] and institutions [30].

This bibliometric analysis is primarily based on the Web of Science. It is analyzed by a bibliometric survey that major scientific article analysis publications are from conferences, journals and articles from Chinese publications, followed by

India and Egypt. Most of the research publication is by the subject areas of Engineering and Mathematics, followed by Computer Science. The aim of this bibliometric study is to understand the extent of the scholar literature for the area of chaotic cryptography to highlight significant, influential aspects, research streams, and themes. The question is why developing countries are greatly interested in this field?

The rest of the paper is organised as follows. Section 2 presents the chaotic cryptography area using VOS viewer. Section 3 develops a graphical analysis of the bibliographic data of the social structure about chaotic cryptography. Section 4 presents a bibliometric analysis and visualisation, and Section 5 gives a short conclusion.

II. AREAS OF CHAOTIC CRYPTOGRAPHY WITH VOS VIEWER

First, this is an analyzation of the most researched area of chaotic cryptography journals of published documents using VOS viewer which is [31] a freely available software that collects the bibliometric data for analysis and visualization by using several bibliometric indicators including bibliometric coupling, citation [32], co-citation analysis [33] co-authorship [34] and co-occurrence of keywords [35]. The VOS viewer is particularly useful for displaying large bibliometric maps in easily interpreted ways.

Recall that research areas intend to facilitate the identification and selection of the best resources and tools. Explore our Research Areas to learn more about chaotic cryptography, literature, and recent news. Figure 1 shows 30 keywords of one hundred citations and the one hundred most representative connections, using 50 clusters. It shows that the most known areas on chaotic cryptography are: Chaotic encryption, decryption, logistic map, chaotic map, cryptography, information security, S-box, diffusion, permutation, encryption, map, crypto-system, chaos, image encryption, security analysis, cryptanalysis, color image encryption, chaotic systems, security, algorithm, synchronization, scheme, transform, hyper-chaotic system, compression, chaotic system, breaking, design, secure communication, systems. By combining those keywords, researchers can develop new ideas and find new advanced solutions in the chaotic cryptography domain.

III. SOCIAL STRUCTURE (COUNTRIES, SOURCES AND RELEVANT AUTHORS)

The information's about countries collaboration, the most relevant ones depending on articles number and researchers active in the field, the most relevant sources and authors, are all generated using 'biblioshiny' a web-interface of the 'bibliometrix 3.0' package of R-studio, referring to the totality of 2607 articles.

A. Countries

A total of 80 countries made contributions in chaotic cryptography research. Figure 2 presents the thickness of the link between two countries is indicative of the extent of co-authorship (collaboration). We can understand from Figure

2 the collaboration between countries around the world. It shows a sticker link between every two countries. From the perspective of each country's contribution, Saudi Arabia, Egypt, China, and the USA are the leading countries by having 67, 57 and 40 publications over 343 entries (at least one of the authors is in the country).

TABLE I
MOST RELEVANT COUNTRIES DEPENDING ON ARTICLES NUMBER

Countries/Regions	Citizens of the country (World bank)	Articles number	Ratios
Saudi Arabia	34.81 millions	154	1/226 thousands
Tunisia	11.82 millions	50	1/236 thousands
Egypt	102.3 millions	161	1/635 thousands
Peoples R China	1.402 billions	1399	1/1 million
Lithuania	2.8 millions	2	1/1.4 millions
France	59.55 millions	41	1/1.45 millions
Pakistan	220.9 millions	150	1/1.5 millions
India	1.38 billions	389	1/3.547 millions
Italy	59.55 millions	9	1/6.6 millions

TABLE II
MOST RELEVANT COUNTRIES DEPENDING ON RESEARCHERS ACTIVE IN THE FIELD.

Countries/Regions	Citizens of the country (World bank)	Researchers active in the field	Ratios
Tunisia	11.82 millions	77	1/154 thousands
Egypt	102.3 millions	172	1/595 thousand
Lithuania	2.8 millions	4	1/700 thousands
Saudi Arabia	34.81 millions	33	1/1 million
Pakistan	220.9 millions	124	1/1.8 millions
France	59.55 millions	30	1/2 millions
Italy	59.55 millions	12	1/5 millions
India	1.38 billions	200	1/6.9 millions
Peoples R China	1.402 billions	200	1/7 millions

Table 1 shows Saudi Arabia's remarkable contribution of 1/226 thousands share of the total population compared to her publications, which is the highest record followed by Tunisia, Egypt, and Peoples R China. Lithuania contributed

Access with 227 papers. This table helps researchers to find the best journal where to publish their new discoveries.

TABLE III
MOST RELEVANT SOURCES.

Sources	Articles
MULTIMEDIA TOOLS AND APPLICATIONS	335
IEEE ACCESS	227
NONLINEAR DYNAMICS	132
OPTICS AND LASERS IN ENGINEERING	74
ENTROPY	71
OPTIK	61
SIGNAL PROCESSING	59
INTERNATIONAL JOURNAL OF BIFURCATION AND CHAOS	57
JOURNAL OF INFORMATION SECURITY AND APPLICATIONS	43
OPTICS AND LASER TECHNOLOGY	40

Those sources can help researchers in chaotic cryptography to find easily the best journal, where to publish their new contributions.

C. Relevant author

The highest rate of publications authors and their annual production over the years according to the Web of Science library are Xingyuan Wang and and Yong Zhang with the longest period of contribution to the field. For instance, Wang's name has appeared in 140 papers for 2015–2021, his most cited article titled “A novel chaotic block image encryption algorithm based on dynamic random growth technique” [36] in 2015 with 273 total citations. Zhang has over 75 publications from 2015-2021, his most cited article named “The unified image encryption algorithm based on chaos and cubic S-Box” [37] in 2018 with 98 total citations.

Those in formations can help researchers interested in chaotic cryptography to have an idea, how to excel when writing their results.

IV. ANALYSIS AND VISUALISATION

The analysis and visualisation about the three field analysis, chaotic cryptography categories, top articles and the most global cited documents, are all generated using ‘biblioshiny’ a web-interface of the ‘bibliometrix 3.0’ package of R-studio, referring to the totality of 2607 articles from Web of Science library.

A. Three field analysis

Figure 3 presents the three-field. analysis of chaotic cryptography publications with a keyword plus are on the left side of the figure, affiliations are on the right, and countries of interest are in the middle. The figure shows that the China is working with most of the top affiliations such dalian maritime university, henan university, dalian university technology. Concerning topics it's using algorithm, system, scheme, map, permutation, chaotic system, synchronization, cryptanalysis, and encryption.

B. Web of science Categories

Table 4 shows the categories of chaotic cryptography. It's clear that Engineering electrical electronic takes 40.153% of publications, the Computer science and information systems with 33.346% and telecommunications with 15.488%. This analysis makes sense because it is a theme that concerns data security using software and hardware.

This can reassure software and electronic engineers, that this areas interests all of them.

TABLE IV
CHAOTIC CRYPTOGRAPHY CATEGORIES.

Web of Science Categories	Record Count	% of 2607
Engineering Electrical Electronic	1050	40.16
Computer Science Information Systems	872	33.35
Computer Science Theory Methods	419	16.02
Telecommunications	405	15.49
Optics	390	14.91
Computer Science Software Engineering	383	14.65
Physics Multidisciplinary	228	8.72
Mathematics Interdisciplinary Applications	180	6.89
Computer Science Artificial Intelligence	173	6.67
Multidisciplinary Sciences	155	5.93

C. Top Articles

The most global cited article titled [42] “2d sine logistic modulation map for image encryption.” by Zhongyun Hua, Yicong Zhou, Chi-Man Pun and C.L. Philip Chen in 2015 and the second one [43] titled “Image encryption using 2d logistic adjusted-sine map.” by Zhongyun Hua and Yicong Zhou in 2016. Table 5 contains the twenty most global cited references with their total cited numbers, their total cited number per year, their normalized total cited number, their countries name, their journals and their publication years. The most local cited article titled [38] “A novel image encryption scheme based on substitution-permutation network and chaos” by Akram Belazi in 2016 and the second one [39] titled “A new color image encryption using combination of the 1D chaotic map” by Chanil Pak.

We found those results from the 2607 scientific journal articles related to chaotic cryptography from 2015 to 2021 taken from Web Of Science library applied in R-studio software with the “Biblioshiny” package. Also, the most cited article published by Xingyuan Wang and Suo Gao in 2020 named [40] “Image encryption algorithm based on the matrix semi-tensor product with a compound secret key produced by a boolean network.” in the Information Sciences journal, it is cited 97 times in total. And the most cited article in 2021 named [41] “Fractal sorting matrix and its application on chaotic image encryption” in the Information Sciences journal, it is cited 72 times in total.

TABLE V
MOST GLOBAL CITED DOCUMENTS

Paper	TC	TC per Year	Normalized TC	Country	Name of the Journal	Year
2d sine logistic modulation map for image encryption. [42]	354	44.25	11.5052	China	Information Sciences	2015
Image encryption using 2d logistic adjusted-sine map. [43]	324	46.286	10.9624	China	Information Sciences	2016
A novel chaos-based image encryption algorithm using dna sequence operations. [44]	295	49.167	10.248	USA and China	Optics and Lasers in engineering	2017
A novel chaotic image encryption scheme using dna sequence operations. [45]	293	36.625	9.5226	China	Optics and Lasers in engineering	2015
A novel bit-level image encryption algorithm based on chaotic maps. [46]	287	41	9.7105	China	Optics and Lasers in engineering	2016
A novel chaotic block image encryption algorithm based on dynamic random growth technique. [47]	273	34.125	8.8726	China	Optics and Lasers in engineering	2015
A novel image encryption scheme based on substitution-permutation network and chaos. [48]	249	35.571	8.4248	Egypt	Signal Processing	2016
A new color image encryption using combination of the 1d chaotic map. [49]	245	40.833	8.5111	China and North Korean	Signal Processing	2017
A fast image encryption algorithm based on chaotic map. [50]	225	32.143	7.6128	China	Optics and Lasers in engineering	2016
A color image cryptosystem based on dynamic dna encryption and chaos. [51]	215	53.75	14.9625	China and USA	Signal Processing	2019
Image compression-encryption scheme based on hyper-chaotic system and 2d compressive sensing. [52]	207	29.571	7.0038	China	Optics and Laser Technology	2016
Cosine-transform-based chaotic system for image encryption. [53]	194	48.5	13.5011	China	Information Sciences	2019
A hyper-chaos-based image encryption algorithm using pixel-level permutation and bit-level permutation. [54]	191	31.833	6.6352	China	Optics and Lasers in engineering	2017
On the cryptanalysis of fridrich's chaotic image encryption scheme. [55]	186	31	6.4615	China	Signal Processing	2017
2d logistic-sinecoupling map for image encryption. [56]	185	37	8.3812	China	Signal Processing	2018
A novel chaos-based image encryption using dna sequence operation and secure hash algorithm sha-2. [57]	169	24.143	5.718	Tunisia	Nonlinear Dynamics	2016
a rgb image encryption algorithm based on total plain image characteristics and chaos. [58]	166	20.75	5.3951	Mexico	Signal Processing	2015
A new color image encryption scheme based on DNA sequences and multiple improved 1D chaotic maps. [59]	165	20.625	5.3626	China and Germany	Applied Soft Computing	2015
Color image encryption based on hybrid hyper-chaotic system and cellular automata. [60]	162	27	5.6277	Iran	Optics and Lasers in engineering	2017
Theoretical design and fpga-based implementation of higher-dimensional digital chaotic systems. [61]	160	22.857	5.4135	China and France	IEEE Transactions on Circuits and Systems	2017

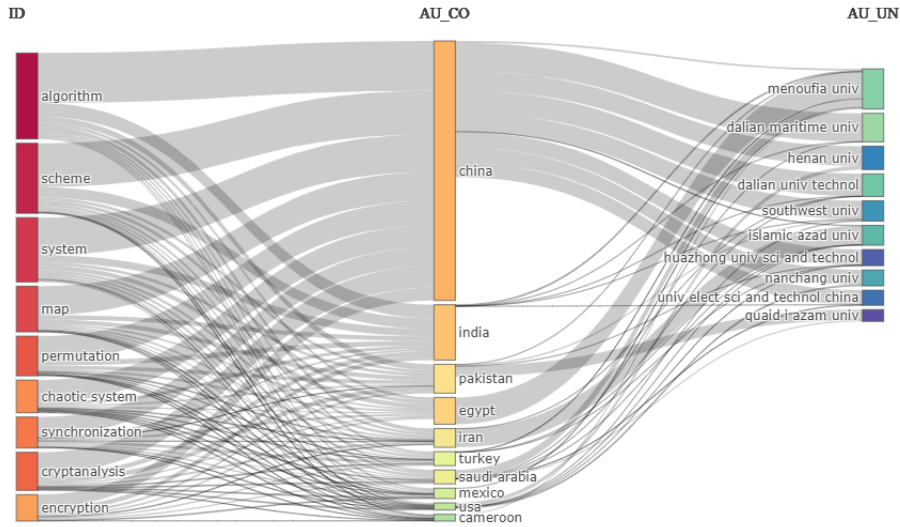


Fig. 3. Three-field visualization depending on keywords, countries and affiliations.

Those articles and the top 20 cited in Table 5, can help researchers to develop new ideas in this field after reading them.

V. CONCLUSION

This study develops a graphical visualization of the results with the help of VOS viewer and R-studio softwares. The work shows the publication structure of authors, countries, and institutions, by considering bibliographic coupling, citation analysis and co-occurrence of author keywords. The softwares also visualize the most cited chaotic cryptography journals through co-citation analysis. The graph reveals that most of the journals cited are related to Engineering Electrical Electronic, Computer Science and Information Systems. The graphical study ends with an analysis of most frequent articles. The leading topics of the journal are algorithm, system, scheme, map, permutation, chaotic system, synchronization, cryptanalysis and encryption. What we found unusual, is that developing countries are those who are publishing the most about chaotic cryptography, usually developed countries are always in the 80% rate. Approximately, developing countries have the chance to be leader in chaotic cryptography, they can work hard on its special strength to impact the world.

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