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Supercomputers and Quantum Computing on the Axis of Cyber Security

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Abstract

Cybersecurity has become a very critical area to address for governments, industry and the academic community. Cyber attacks are on the rise so is research to address the challenges presented by these attacks. Research yields several technological advancements. This paper explores the development of quantum computing and supercomputers within the context of cybersecurity. As many governments and organizations are under the threat of cyber-attacks, it is critical and timely to explore the status of technological development. We use advanced scientometric techniques to disclose the development status and identify the centers of excellence. The research uses bibliometric data of published papers and utilizes an integration of scientometric methods including social network analysis, entropy analysis, cluster analysis, overlay maps and knowledge diffusion analysis as well as keyword and source analyses.

Keywords: Cybersecurity; Quantum Computing; Bibliometrics; Research Landscape

Introduction

Quantum computing and supercomputers are technologies that have the potential to revolutionize many industries, but also carry significant cybersecurity risks (Agnihotri & Pandya, 2021; Brijwani et al., 2023). Quantum computers can handle much larger data sets than even the world's most powerful supercomputers based on classical computing, while they have the power to perform much more complex calculations (Arshad & Riaz, 2023). Although quantum computers are still in their infancy, they have the potential to be considered in terms of cybersecurity threats. Quantum computing, on the other hand, is a phenomenon that should be considered as a technology that will enable great innovations in the future but will also bring various risks (Arshad & Riaz, 2023; Brijwani et al., 2023; Dupont, 2013). The quantum cybersecurity threat includes data breaches of sensitive health and financial personal data, challenges to the integrity of digital assets and the underlying cryptography underlying cryptocurrencies, etc. poses potential dangers. Noting that the effects of quantum computing in terms of cyber security are quite profound, studies recommend taking a series of precautions, especially personal passwords (Denning, 2019; Mosca, 2018).

Literature Review

Navigating the competitive landscape of global research and development, decision-makers and researchers, as highlighted by Iwami et al. (2014), must skillfully identify promising research areas. In the realm of nanotechnology, the progress is intricately tied to global collaboration, with patents serving as pivotal indicators of technological activities globally (Moughari & Daim, 2023). However, the understanding of factors extracted from patent records is an evolving field with immense potential to guide research and economic endeavors.

In the nanotechnology sector, Bass and Kurgan's (2010) study employs machine learning techniques to characterize patents, considering numerical features related to inventors, assignees, patent classification, and references. Kang et al. (2023) investigates the interconnections between scientific and technological activities in nanotechnology, revealing dynamic relationships and development opportunities in the semiconductor industry.Wong et al. (2007) introduce a unique method for categorizing commercial applications, emphasizing initial instrumentation that has evolved into diverse application areas. The substantial role of universities, particularly in the United States, the United Kingdom, and Canada, in nanotechnology patenting is notably emphasized. Zheng's study (2014) unveils a consistent uptrend in nanotechnology patents through global collaboration, prominently led by the USA, while Asian countries escalate their participation and European nations exhibit a decline. Collaboration styles, such as extensive partnerships in the USA and selective collaborations in Spain, Israel, Russia, Singapore, and Taiwan, play a crucial role in shaping the nanotechnology landscape.

In rapidly evolving industries like nanotechnology, collaboration proves pivotal for knowledge and innovation creation, with centralized researchers positively impacting knowledge flows, as highlighted by Zamzami & Schiffauerova (2017). Recognizing and tracking business and technological trends remain vital for innovation and competitiveness (Moughari & Daim, 2023). Saritas et al.'s (2021) study leverages the exponential growth of global data using text-mining and semantic analysis to explore trends in mobile commerce (m-commerce). Employing intelligent big data analytics, including natural language processing and technology analysis, the study identifies critical technologies, providing a comprehensive overview of the m-commerce landscape. In essence, international collaboration is recognized as a strategic policy to enhance scientific competency globally, acknowledging that no single country possesses all the resources to address complexities, allocate funding, and tackle global challenges (Moughari & Daim, 2023). To facilitate this, countries employ institutional mechanisms such as bilateral agreements and specialized centers, strategically promoting international collaboration (Bhattacharya & Kaul, 2015). Parreira et al. (2017) found that international collaboration in ecology has a moderate spatial structure, with collaboration decreasing as the geographic distance between countries increased, emphasizing shared trade blocs, similar Human Development Index, comparable scientific structures, and geographic proximity among highly collaborative countries.

Shifting focus, Goh et al. (2020) emphasize the superiority of machine learning models over human classifiers in scientific research abstract categorization, consistently demonstrating higher accuracy and reliability across diverse datasets and evaluation panels. Simultaneously, Maciel et al. (2019) delve into the profound influence of the US defense and intelligence community on information and communication technologies (ICTs), unveiling key paradigms like quantum science and graphene advanced within this strategic context. In exploring knowledge production trends in quantum technology research, Jang B. et al. (2022) shed light on China's emphasis on domestic collaboration, communication technology, and core-periphery partnerships, contrasting with the US, which prioritizes both domestic and international collaboration, particularly in computing technology and the strengthening of OECD-country partnerships. Concurrently, Bashirpour Bonab et al. (2023) introduce the Quantum City paradigm, offering a conceptual lens for understanding urban complexity by emphasizing quantum communication and quantum computing for urban planning.

Transitioning to a broader perspective, Chavalarias et al. (2022) formally introduce concepts of levels and scales in the dynamics of knowledge, presenting phylomemies and their associated phylomemetic networks. Tattershall et al. (2021) model the temporal dynamics of 200 scientific topics using Logistic and Gompertz models, showcasing algorithmic topic extraction across diverse scientific disciplines. Coccia (2020) delves into the dynamics of science, focusing on properties such as scientific fission and ambidextrous drivers of science.

Examining the intricate interconnections between patents and scientific literature, Qi et al. (2018) discern evolution patterns and distinct keywords over two decades. Utilizing Zipf's law for information retrieval, Quoniam et al. (1998) create a graphical depiction of keywords within a dataset. Balaban & Klein's scientometric analysis (2006) challenges the designation of chemistry as 'The Central Science,' indicating biochemistry's stronger interconnections with other sciences.

Omar et al. (2017) anticipate future trends and explore convergence in their analysis of the global presence of AI among professionals, artists, programmers, and researchers. Investigating the influence of social integration on scientists' research activity and performance, Rey-Rocha et al. (2007) find increased collaboration and patenting rates among highly integrated researchers. Rey-Rocha et al.'s (2015) study of basic-clinical collaboration in Spanish National Health System-affiliated hospitals reveals enhanced productivity with clinical collaboration and improved scientific production quality with translational research involvement. Antonio-Garc et al.'s (2014) investigation identifies factors influencing the activity and performance of researchers in the Spanish National Health System.

Examining the distribution of characteristics among computer scientists in Brazil, Arruda et al. (2009) define computer scientists as faculty in graduate-level computer science departments, providing insights into regional and gender-based distinctions. Sobkowicz (2011) introduces a computer model for opinion dynamics in scientific communities, exploring conditions for theory dominance or coexistence. Smith et al.'s (2023) assessment of the financial consequences of the US cyberinfrastructure project XSEDE underscores its importance, providing operational and support services for advanced technology, cloud systems, and supercomputers. Recognizing China's historical challenges in science and technology leadership, Basu et al. (2018) offer insights into its advancements.

Ortega et al. (2008) map the web presence of European universities at the university level, using hyperlinks to aggregate distinct national networks. Addressing the challenge of automated literature reviews, Portenoy and West (2020) propose a framework utilizing reference lists from existing review papers as labeled data, adept at identifying pertinent papers. Finally, Fields (2015) investigates Nobel laureates in Physiology or Medicine between 1991 and 2010, finding cross-disciplinary brokers, researchers publishing in both biomedical and non-biomedical disciplines, to be at most 2.8 co-authorship steps away from these laureates.

Zou et al. (2023) explores the evolution of digital finance literature, revealing four thematic streams, while Huang et al. (2023) identifies trends in autonomous vehicle research, highlighting a focus on data-driven innovation and a gap in social science research integration. Vishwakarma et al. (2024) conducts a bibliometric analysis and systematic literature review on social robots in service operations, introducing a research framework and revealing widespread adoption in industries like travel and hospitality.

Other studies include Özköse and Güney (2023) analyzing the relationship between Industry 4.0 and productivity, Al-Qaysi et al. (2023) reviewing the adoption of social media in instructional activities, and Al-Emran and Griffy-Brown (2023) emphasizing the importance of digital technologies in achieving sustainable development. Additionally, Verma et al. (2023) examined the organizational architecture of strategic entrepreneurial firms undergoing digital transformation, and Vatankhah Barenji et al. (2024) explored strategies to enhance pharmaceutical product quality and consistency in Pharma 4.0. These studies demonstrate the significant impact of technology on various fields and industries.

Methodology

Bibliometrics is a method used to determine science, technology and innovation policies by adapting mathematical and statistical methods to scientific communication environments (Pritchard, 1969). The outputs obtained thanks to this method provide the opportunity to make inferences about scientific communication, its direction, determination of the dominant actors, author productivity, institution efficiency and organizational efficiency (Doğrul et al., 2023; Öztürk & Yalçın, 2022; Yalçın & Daim, 2021; Yalçın & Şeker, 2020). Recently, the results obtained by using social network analysis, bibliometrics and scientometric methods together have turned into a frequently used method in technology and engineering management called technology mining (Daim & Yalcin, 2019). Figure 1 provides a flowchart of the analyses established.

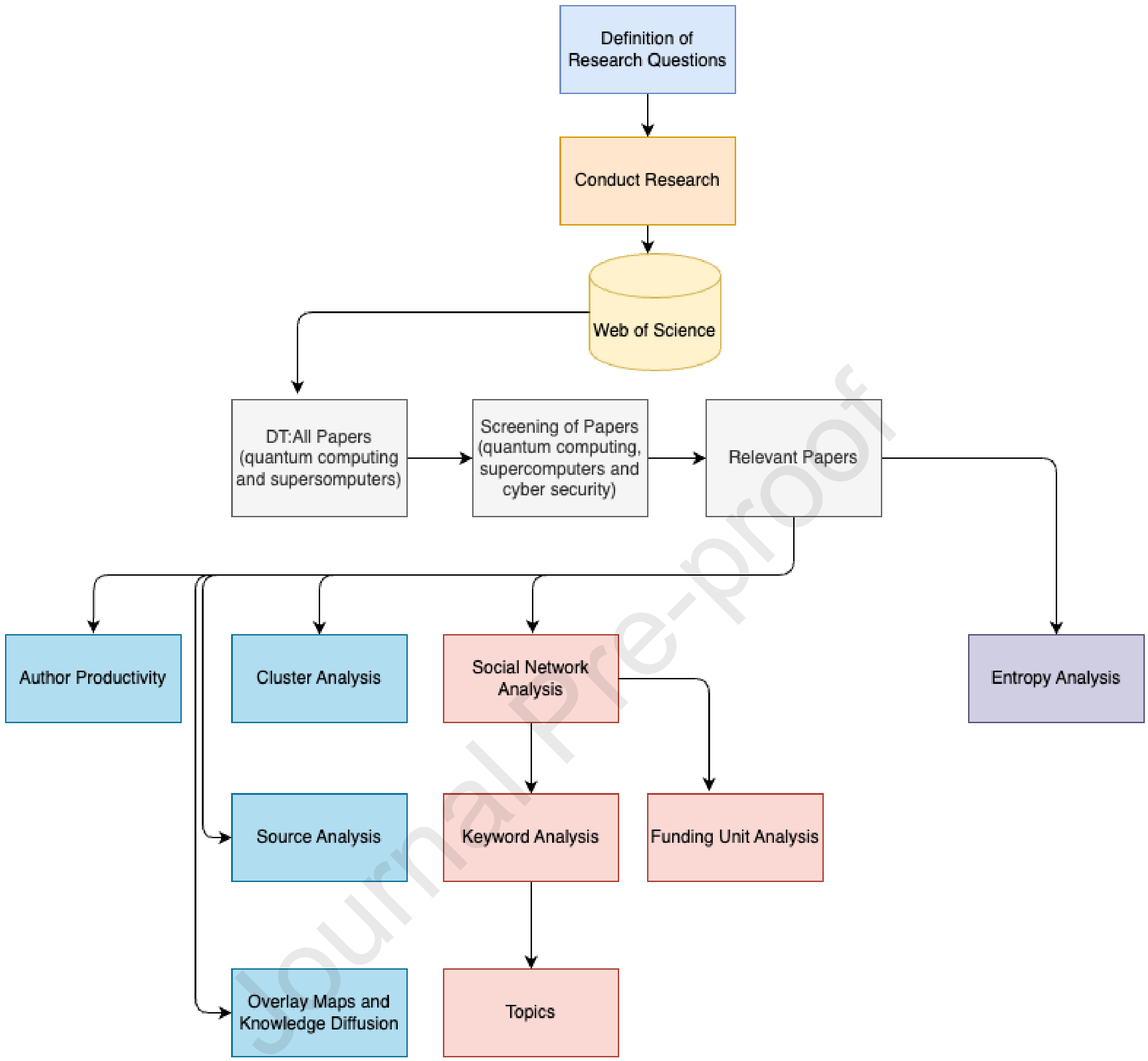

Figure 1 – Research Methodology

The objective of this research was to reveal the dynamics of the combined use of these 3 technologies in the axis of quantum computing, supercomputers and cybersecurity. In this way, in eliminating cyber security threats that may arise in the daily workflow where information systems are used intensively, the potential usage areas, advantages and disadvantages of quantum computing and supercomputers, the identification of developing technology domains in these subjects, the detection of points that have reached the level of technological saturation, and also the development The techmining method, which aims to identify open - relatively untouched - areas, was used. Bibliometrics can be used to study the impact of quantum computers in technology management. Bibliometric analyzes can be used for the evolutionary analysis of technology policies, as well as for the evaluation of research outputs. This method, which is also very useful in terms of providing outputs for the examination of the management thought system, when combined with scientometrics and social network analysis (SNA), will reach the capabilities of the technology mining method and provide a useful tool in a wide range of fields, from the determination of technology domains that will gain importance in the field, to the determination of researchers, institutions and countries that shape the field. In the study, an online search was carried out in the citation indexes of the Web of Science database in order to access the information of scientific documents in international directories on the relevant subject. The results obtained were kept in a relational database. Necessary data cleaning procedures were carried out to make the data ready for analysis. Afterwards, the necessary analysis within the research structure was carried out. In order to ensure that the information obtained was refined, first the data of scientific documents on quantum computing and supercomputers (38,704 scientific documents) were compiled, and then the information of scientific documents on quantum computing, supercomputers and cyber security were compiled within this data set. The dataset contains a total of 1,774 documents collected over a period from 1978 to 2023 and obtained from 791 different sources (articles, books, etc.). The annual growth rate of the data was recorded as 11.25% and the average age of the documents was calculated as 12.9 years. Each document was cited an average of 15.51 times and contained 54,746 references in total. These data highlight the importance of this broad and rich field of research, which includes the leading topics of cybersecurity, supercomputers, and quantum computing. This analysis shows that developments in these areas are accelerating rapidly and that these technologies could have a major impact on future cybersecurity strategies.

Keyword Analysis

Co-word analysis is a text mining method used in the context of science technology policy development (Derrick et al., 2014; Talafi et al., 2018). Thanks to this method, it is possible to identify relationships and contacts between many text documents or articles (Daim & Yalçın, 2022). It was preferred in our study since it is a powerful tool preferred for understanding contacts, trends and relationships in the mentioned areas. We perform keyword analysis in order to closely see the challenges and benefits of quantum computing and supercomputer infrastructure to cyber security research. Within the scope of this analysis, we used social network analysis (SNA) metrics that address the frequency of occurrence of words together. In this context, we carried out the necessary analyzes to detect betweenness centrality, degree, nodes with high constraint rates and nodes with low constraint rates. The results obtained thanks to this method, also called structural hole analysis (Burt, 2015), enabled us to identify both research areas that are open to development and research areas that are at a very high level in terms of constraint rate, in other words, research areas that have reached the saturation level (Figure 2).

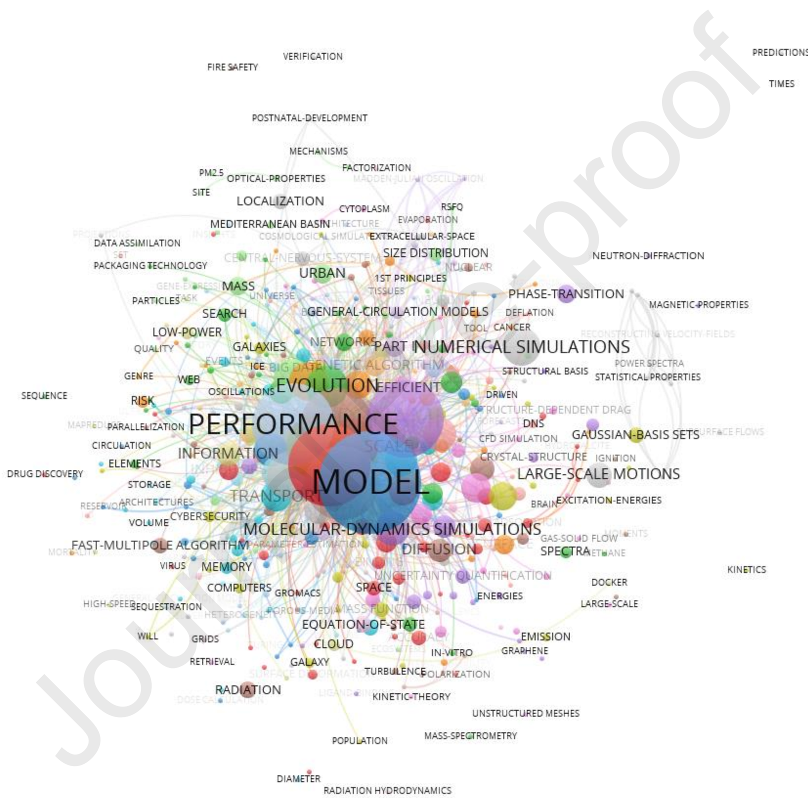

Figure 2: Co-Word Analysis (Keyword Plus)

These keywords are paired with SNA metrics to help understand the dynamics and interactions in the cybersecurity and quantum computing environment. In this context, the “degree” of connectivity between security measures, the “betweenness centrality” critical security nodes, and how “aggregate constraints” affect the overall security posture can be analyzed (Alhajj & Rokne, 2014; Bonchi et al., 2011). This analysis can provide valuable insights into optimizing security and resource allocation in the field of quantum computing by considering the network-like relationships between the various components and entities involved (Table 1).

All Degree	**Betweenness centrality**	**High Aggregate constraints**	**Low Aggregate constraints**
MODEL	MODEL	MODEL	PREDICTIONS
ALGORITHM	ALGORITHM	PERFORMANCE	TIMES
PERFORMANCE	PERFORMANCE	DYNAMICS	REGRESSION
SYSTEMS	DYNAMICS	MODELS	I/O
SIMULATIONS	SYSTEMS	ALGORITHM	PACKAGING TECHNOLOGY
DYNAMICS	MODELS	SYSTEMS	VERIFICATION
MODELS	SIMULATIONS	SIMULATIONS	SET
PREDICTION	SIMULATION	PREDICTION	GRIDS
SIMULATION	PREDICTION	SYSTEM	DOSE CALCULATION
OPTIMIZATION	OPTIMIZATION	ALGORITHMS	RADIATION HYDRODYNAMICS
SYSTEM	SYSTEM	SIMULATION	LAND
ALGORITHMS	ALGORITHMS	OPTIMIZATION	DIRECT NUMERICAL SIMULATIONS
EVOLUTION	EVOLUTION	IMPLEMENTATION	FIRE SAFETY
VARIABILITY	VARIABILITY	MOLECULAR-DYNAMICS SIMULATIONS	KINETICS
MOLECULAR-DYNAMICS SIMULATIONS	NUMERICAL SIMULATIONS	DESIGN	MAGNETIC-PROPERTIES
FRAMEWORK	IMPACT	EVOLUTION	INSIGHTS
IMPLEMENTATION	FRAMEWORK	VARIABILITY	DRUG DISCOVERY
SOLVER	MOLECULAR-DYNAMICS SIMULATIONS	IDENTIFICATION	NEUTRON-DIFFRACTION
NETWORK	SOLVER	SCALE	LUNG
TRANSPORT	FLOW	FLOW	MECHANISMS
ENERGY	DESIGN	TRANSPORT	RSFQ
SCALE	IMPLEMENTATION	PARALLEL	QOS
IMPACT	SCALE	ENERGY	INTEGRATED SERVICES NETWORKS
IDENTIFICATION	TRANSPORT	GROWTH	PROCESSOR SHARING APPROACH
FLOW	BEHAVIOR	TIME	FLOW-CONTROL

Table 1 Keyword Analysis

When we examine the keywords that stand out within the framework of the level of connectivity (All Degree), we can say that the concepts and concepts underlying the relevant technologies stand out (Ding et al., 2019). To explain it this way: the development and use of these technologies are making a huge impact in many areas. While "model" shows that the concept of modeling stands out as an important tool for quantum computing and supercomputers, it is also known that modeling is used in cyber security to detect and prevent attacks. While “algorithms” stand out as a key component for quantum computing and supercomputers, the use of these technologies allows the development of more complex algorithms. On the other hand, in cyber security, algorithms are used to detect and prevent attacks. Quantum computing and supercomputers are used for high-performance computing (Dou et al., 2022). While these technologies are designed to perform faster and more efficient calculations, it is known that quantum computing and supercomputers are used to provide the concept of performance as an important component in the detection and prevention of attacks in cyber security (Makarov et al., 2006; Wiechers et al., 2011). Quantum computing enables the design and analysis of complex systems, especially supercomputers and cybersecurity. While simulations stand out as an important tool for quantum computing and supercomputers, simulations in cyber security are used to detect and prevent attacks. Prediction is used to predict the behavior of complex systems in the development of new technologies for quantum computing and supercomputers. Additionally, in cybersecurity, prediction is used to detect and prevent attacks. When considered in this respect, it is possible to say that nodes with a high level of connectivity form an important basis for quantum computing, supercomputers and cyber security axis. The concept of High Aggregate constraints is used to determine that certain elements within a network have more control or influence over others (Yalcin et al., 2022). The fact that these keywords have "High Aggregate constraints" values shows that they are of critical importance in the fields of quantum computing and cyber security and have a great impact on other elements. Considered from this perspective, in terms of quantum computing, the keywords "MODEL" and "ALGORITHM" can be interpreted as playing a critical role in the development of quantum algorithms and models, while "SIMULATIONS" and "MOLECULAR-DYNAMICS SIMULATIONS" are important for performing simulations of quantum systems. "DESIGN" and "IMPLEMENTATION" can be effective in the physical design and implementation of quantum computers. While "OPTIMIZATION" and "ALGORITHMS" draw attention as concepts of great importance in optimizing quantum algorithms and processes, "ENERGY" and "TRANSPORT" indicate studies that prioritize critical elements for the energy efficiency and information transmission of quantum computers. When we look at it in the context of cyber security, it is observed that the keywords "PERFORMANCE" and "IDENTIFICATION" refer to studies aimed at identifying and monitoring cyber-attacks, while "SYSTEMS" and "SCALE" refer to studies examining the size and complexity of cyber security systems. It should not be forgotten that these concepts can directly affect the management of cyber security policies. The concepts of "FLOW" and "TRANSPORT," have taken their place among the nodes that have strengthened their place in the network as components that emphasize controls over network traffic and data transmission and play a vital role in the implementation of cyber security measures. While "GROWTH" and "TIME" are among the concepts necessary to understand how cyber threats and networks change over time, it is possible to say that these concepts have collectively strengthened their place in the network, in other words, they have reached the saturation level (see high aggregate constraints).

Cluster Analysis

Cluster analysis is a statistical method used to separate data with similar characteristics into groups (Blashfield & Aldenderfer, 1978). It can be used to create a visual representation of scientific literature, as well as to track how scientific studies and research are interconnected, which topics influence each other and which areas are more concentrated, and how a particular field changes over time (Ahsan et al., 2022; Zhang & Zou, 2022). It is a method that can serve several specific purposes, such as classifying research areas and identifying science and technology clusters. In our study, the 9 largest clusters that emerged in the clustering analysis carried out for these purposes are presented visually (Figure 3).

Cluster 0 "electronic structure code" includes research on electronic structure code in the field of cybersecurity. It can be said that it includes the development or analysis of the code used in electronic security systems. Cluster 1, called the "stochastic multi-cloud model", consists of research on modeling and analyzing security in multi-cloud environments. The "Grip computing" cluster is related to grid computing in the context of cyber security. An approach that consists of combining computer resources from multiple locations to achieve a common goal. This cluster, which consists of studies examining the effects of grid computing on distributed security systems, can be shown as one of the prominent clusters in terms of showing the importance of distributed computing in cybersecurity research. Cluster 3 (Dimension: 32, Silhouette: 0.758, Label: "efficient massive parallel", Average Year: 2005) : This cluster may relate to efficient massively parallel computing techniques in cybersecurity May include research to optimize parallel processing for security-related tasks Cybersecurity and Supercomputers (Cluster 4 and Cluster 5): Supercomputers address large and complex cybersecurity problems It consists of studies that seek answers to the question of whether it can be a powerful tool for While Cluster 4 contains information about supercomputer systems, research in these clusters has focused on the abilities of supercomputers to detect cybersecurity threats, block attacks, and protect networks. When we consider it in terms of Cyber Security and Quantum Computing (Potential connections Cluster 0, Cluster 1, and Cluster 6): Quantum computing is a technology that stands out with its potential to solve mathematical problems that classical computers cannot solve.

While Cluster 0 and Cluster 1 focus on specific calculation and modeling issues, they can be described as studies that examine in depth how quantum computing can be used in terms of security or what its effects may be. Cybersecurity and DNA-Based Supercomputers (Cluster 8): DNA-based supercomputers have the potential to offer new approaches to issues such as the development of encryption and security algorithms for cybersecurity applications. Quantum Computing and Cybersecurity (Potential links Cluster 0, Cluster 1 and Cluster 6): Quantum computing has the potential to bring major changes to the fields of cryptography and cryptography (Table 2).

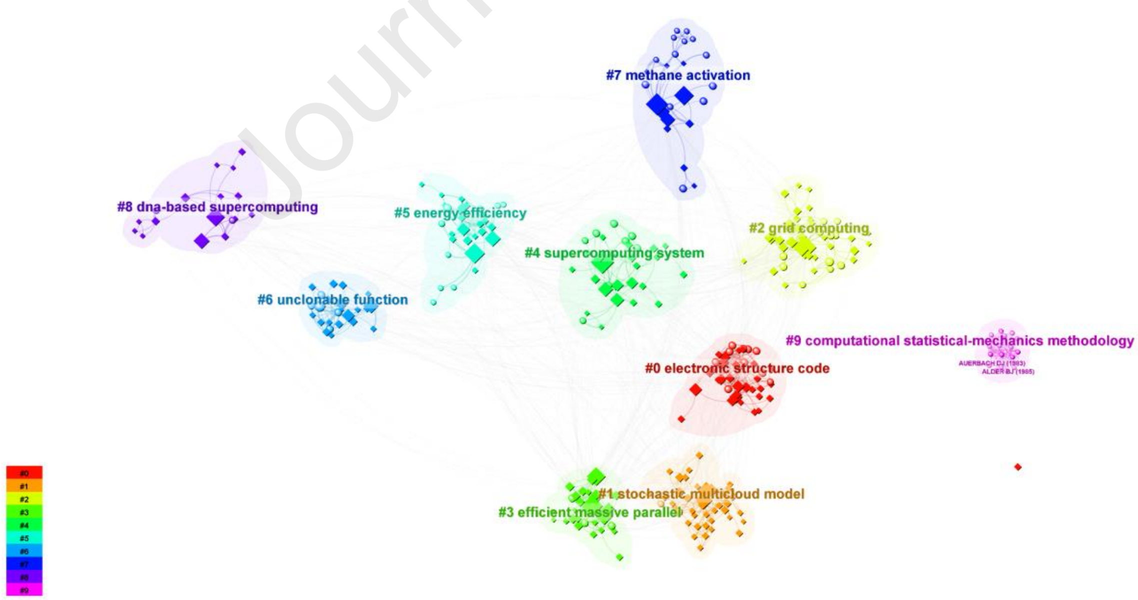

Figure 3: Largest 9 clusters

Table 2: Summary of the largest 36 clusters.

ClusterID	Size	Silhouette	Label (LLR)	Average Year
0	45	0.699	electronic structure code (151.38, 1.0E-4)	2013
1	45	0.747	stochastic multicloud model (333.6, 1.0E-4)	2008
2	42	0.843	grid computing (404.49, 1.0E-4)	2001
3	32	0.758	efficient massive parallel (275.8, 1.0E-4)	2005
4	32	0.763	supercomputing system (188.33, 1.0E-4)	2009
5	30	0.809	energy efficiency (172.9, 1.0E-4)	2003
6	25	0.851	unclonable function (126.9, 1.0E-4)	2016
7	24	0.922	methane activation (238.87, 1.0E-4)	1996
8	18	0.879	dna-based supercomputing (447.93, 1.0E-4)	2000
9	17	1	computational statistical-mechanics methodology application (18.56, 1.0E-4)	1983
10	4	0.996	genetic likelihood (17.52, 1.0E-4)	1989
11	2	1	computational statistical-mechanics methodology application (18.56, 1.0E-4)	1984
12	2	1	large-scale problem (18.56, 1.0E-4)	1988
13	2	1	i-way (17.52, 1.0E-4)	1994
14	2	1	max scientific computer (14.75, 0.001)	1984
15	1	0	supercomputing today (15.79, 1.0E-4)	1981
16	1	0	max scientific computer (14.75, 0.001)	1984
17	1	0	processor interconnection network (18.56, 1.0E-4)	1988
18	1	0	analyzing (17.52, 1.0E-4)	1988
19	1	0	special issue (18.56, 1.0E-4)	1986
20	1	0	universal network (14.75, 0.001)	1983
21	1	0	specific dependence direction (18.56, 1.0E-4)	1998
22	1	0	universal network (14.75, 0.001)	1980
23	1	0	supercomputer calendula fcscl (18.56, 1.0E-4)	2008
24	1	0	supercomputing today (15.79, 1.0E-4)	1982
25	1	0	program (17.52, 1.0E-4)	1988
26	1	0	fault tolerance technique (18.56, 1.0E-4)	1984
27	1	0	radio wave propagation (NaN, 1.0)	1984
28	1	0	scientometric assessment (18.56, 1.0E-4)	2018
29	1	0	nag library (21.33, 1.0E-4)	1988

30	1	0	max scientific computer (14.75, 0.001)	1985
31	1	0	stiffness (16.84, 1.0E-4)	1988
32	1	0	radio wave propagation (NaN, 1.0)	1980
33	1	0	perspective (21.33, 1.0E-4)	1980
34	1	0	global hypermedia system (18.56, 1.0E-4)	1992
35	1	0	clas detector (18.56, 1.0E-4)	1993

In terms of performance indicators and number of publications, "COMPUTER PHYSICS COMMUNICATIONS" and "COMPUTER" journals, which focus on scientific research especially on quantum computing, supercomputers and cyber security, have the highest number of citations and stand out with their important scientific contributions to this field. At the same time, journals such as "JOURNAL OF SUPERCOMPUTING" and "PARALLEL COMPUTING" are among the leading sources in the field. While these data show how frequently these journals are cited by the scientific community and how big an impact they have, they also provide an important guide for researchers who want to follow the most current and influential studies in this field. Therefore, these performance indicators can be used to make a significant contribution to the efforts of researchers on these topics in understanding the literature and identifying important sources, and they are also important in following trends in technology and engineering management. (Table 3).

In our study, a dual layer map base was constructed to visualize interdisciplinary knowledge flow. For this purpose, coordinates were used for both the citation and citation matrices of the journals. In this way, a dual map layer could be created. All logs on a base map were assigned based on the clusters obtained by the Blondel algorithm (Leydesdorff, et al., 2014). While the journals on the left represent the cited journals, the journals on the left contain the cited journals. Thanks to this visual, it is possible to obtain a visualization of knowledge diffusion for journals in the Journal Citation Reports (JCR) journal classification scheme. Figure 4 shows the overlap map analysis results. The analysis provides the identification key groups of research clusters. We see that research in this area are founded on a multidisciplinary areas of research ranging from Medicine to Mathematics. The topics on Figure 4 correspond to journal classifications.

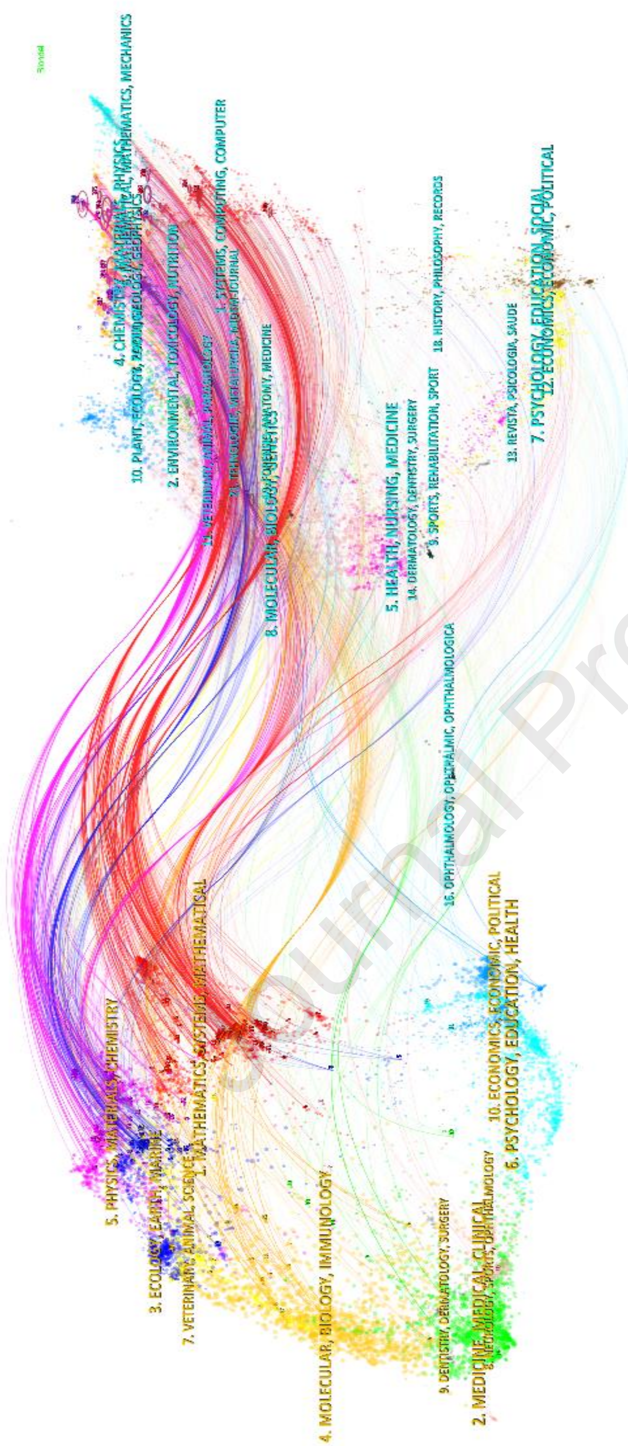

Figure 4: Overlay Map

When we consider it in this context the source list represents a valuable collection of resources that include pivotal scientific publications in the field of supercomputers, quantum computers and cybersecurity. These sources are an indispensable resource for researchers, engineers and industry professionals who want to keep up with the latest developments, new discoveries and technological advances in these fields. Each source hosts many original articles that not only deliver high-quality content but are also evaluated by important metrics such as the H-index, which measures the impact of studies in this field.

Table 3:Source List

SOURCE	Citation sum within h-core	All citations	All articles	h-index
COMPUTER PHYSICS COMMUNICATIONS	480	552	27	12
COMPUTER	459	483	30	11
JOURNAL OF PARALLEL AND DISTRIBUTED COMPUTING	224	269	24	10
CONCURRENCY AND COMPUTATION-PRACTICE & EXPERIENCE	401	456	28	9
IEEE TRANSACTIONS ON PARALLEL AND DISTRIBUTED SYSTEMS	319	365	26	9
FUTURE GENERATION COMPUTER SYSTEMS-THE INTERNATIONAL JOURNAL OF ESCIENCE	178	225	21	9
PROCEEDINGS OF THE IEEE	417	418	11	9
JOURNAL OF SUPERCOMPUTING	129	229	57	8
PARALLEL COMPUTING	255	346	38	8
INTERNATIONAL JOURNAL OF HIGH PERFORMANCE COMPUTING APPLICATIONS	117	167	29	8
IEEE TRANSACTIONS ON COMPUTERS	972	973	9	8
IEEE ACCESS	275	281	11	7
SIAM JOURNAL ON SCIENTIFIC COMPUTING	270	278	10	7
JOURNAL OF COMPUTATIONAL PHYSICS	445	445	7	7
INTERNATIONAL JOURNAL OF SUPERCOMPUTER APPLICATIONS AND HIGH PERFORMANCE COMPUTING	112	135	26	6
COMPUTING IN SCIENCE & ENGINEERING	86	106	19	6
GEOSCIENTIFIC MODEL DEVELOPMENT	317	332	10	6
MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY	432	433	7	6
COMPUTERS & GEOSCIENCES	230	230	6	6
IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION	166	166	6	6
PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A-MATHEMATICAL PHYSICAL AND ENGINEERING SCIENCES	141	163	20	5
SCIENCE	262	272	19	5
NATURE	196	197	16	5
CONCURRENCY-PRACTICE AND EXPERIENCE	79	97	12	5
BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY	236	242	9	5

Researcher Performance

Science and technology play a critical role in the development of nations and increasing their competitiveness (Freeman & Soete, 2009; Kaounides, 1999). Countries are developing policies to use science and technology effectively to meet a wide range of important needs such as economic growth, social welfare, political stability and military defense (Saeed, 1986). However, the success of these policies is directly related to the performance of researchers and productivity in the scientific world (Forero-Pineda, 2006; Freeman & Soete, 2009; Tijssen, 2004). Science and technology policy is a powerful tool that shapes both a country's internal dynamics and international competition, and in this context, the role of scientists, engineers and technologists is extremely important. Experts who can be selected according to their areas of competence will provide significant benefits in the mentioned subjects when employed with the right strategies. In our study, researchers operating in the fields of quantum computing, supercomputers and cyber security were identified and examined according to performance indicators.

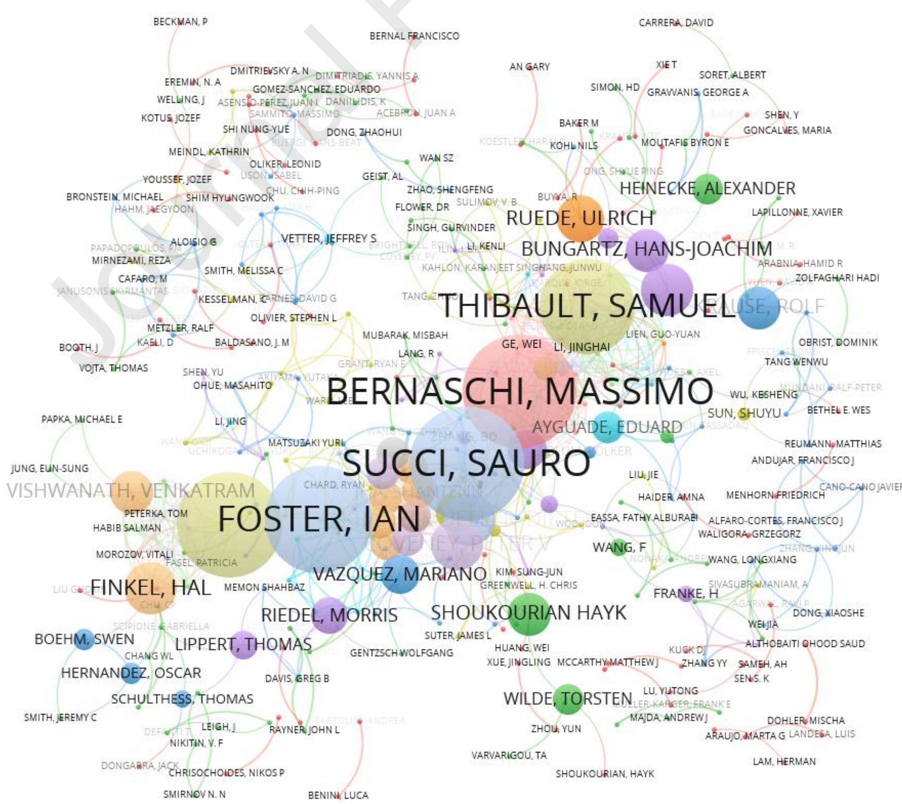

Figure 5: Author Network

Some of the notable authors working in the fields of supercomputers, quantum computers and cybersecurity attract the attention of the scientific community with their high-quality research and contributions (Figure 5).

Among these authors, Ulrich Ruede has a significant H-index and citation count in supercomputers and related fields, while Peter V. Coveney is seen as a prominent name in quantum computers and cybersecurity. N. N. Smirnov is also recognized as a respected writer in this field. In addition, authors such as G. Aloisio and Ji Xu are also known for their valuable work in these fields. These authors have made significant contributions to the development of these technological areas and have carried out effective studies in these areas. H-index values and citation counts show that the works of these authors have a wide impact and have made great contributions to the advancement of their fields. (Table 4)

Table 4: Author Performance Analysis

Author	Citation sum within h-core	All citations	All articles	h-index
RUEDE, ULRICH	163	164	7	6
COVENEY, PETER V	245	247	6	5
SMIRNOV N. N	62	62	5	5
ALOISIO G	78	78	4	4
XU, JI	271	273	6	4
CHRISOCHOIDES, NIKOS P	58	58	4	4
LI, JINGHAI	271	271	4	4
KRAUSE, ROLF	80	80	3	3
METZLER, RALF	76	76	4	3
KESSELMAN, C	69	69	3	3
MOREIRA, J	107	107	3	3
VETTER, JEFFREY S	52	52	4	3
BALDASANO, J. M	127	127	3	3
FENG, WU-CHUN	16	16	3	3
FOSTER, IAN	81	81	3	3
BEEREL, PETER A	20	24	6	3
LI, KENLI	59	60	5	3

CAROTHERS, CHRISTOPHER D	54	54	3	3
COVENEY, PV	63	63	3	3
NESMACHNOW, SERGIO	17	17	3	3
SMITH, JEREMY C	69	69	3	3
WANG, LIMIN	228	228	3	3
LARI KAVEH SOOKHAK	51	51	3	3
RIEDEL, MORRIS	63	63	6	3
MAJDA, ANDREW J	188	188	3	3

In the context of prominent research institutions in the fields of supercomputers, quantum computers and cyber security, institutions such as the University of Illinois and Oak Ridge National Laboratory are among the most influential players in these fields with their high H-index values and number of citations. Universities such as Harvard University and the University of California, San Diego also stand out with their important research in this field. Institutions such as NASA and Lawrence Berkeley National Laboratory are on the list for their critical contributions to space and energy technologies and supercomputers. It can be said that in the list there are some of the institutions that maintain the leadership of these technology fields both in the United States and around the world. Universities such as the University of Tennessee and the University of Maryland have carried out important studies in the fields of cyber security and advanced technology. In addition, national laboratories such as Lawrence Livermore National Laboratory, Los Alamos National Laboratory and Swiss Federal Institute of Technology are leading research organizations in this field. These institutions are important since they provide significant resources and collaboration opportunities that foster progress in these technology areas. (Table 5)

Table 5: Research Organization Performance Analysis

RESEARCH ORGANIZATION	Citation sum within h-core	All citations	All articles	h-index
UNIV ILLINOIS	1640	1995	84	22
OAK RIDGE NATL LAB	1342	1647	73	21
UNIV CALIF BERKELEY	1725	1850	38	19
ARGONNE NATL LAB	1457	1607	42	17
UNIV CALIF SAN DIEGO	1642	1700	30	16
HARVARD UNIV	1937	1958	18	15

UNIV TENNESSEE	742	873	35	15
NASA	352	384	25	12
LAWRENCE BERKELEY NATL LAB	665	736	36	12
UNIV MARYLAND	611	656	20	12
UNIV CHICAGO	931	970	20	11
CHINESE ACAD SCI	511	627	51	11
STANFORD UNIV	400	439	15	10
UNIV MICHIGAN	585	592	14	10
UNIV TEXAS AUSTIN	493	520	19	10
LOS ALAMOS NATL LAB	703	766	27	10
CORNELL UNIV	626	626	13	9
UNIV PITTSBURGH	298	333	17	9
SWISS FED INST TECHNOL	377	414	20	9
LAWRENCE LIVERMORE NATL LAB	404	432	17	9
UNIV SO CALIF	450	464	11	9
UNIV COLORADO	568	582	14	9
SWINBURNE UNIV TECHNOL	189	207	11	8
OHIO STATE UNIV	388	392	13	8
TECH UNIV MUNICH	796	825	17	8

Funding Organizations

It is possible to say that research funding has several outcomes in terms of technology and engineering management (Rull, 2014; Smits & Denis, 2014). Research funding in areas such as cybersecurity and quantum computing is also of great importance. Investments in research funding, which stands out in terms of encouraging technological developments, in other words, investments in research, will increase the potential for developing new and stronger cyber security solutions and faster and more powerful computational methods. In this way, more effective protection against cyber threats can be provided and the qualified information required to make our computers' operations faster and safer can be produced. On the other hand, when the issue is considered from the perspective of national security, it can be said that investments in cyber security research for phenomena that pose a great risk to modern societies, such as cyber-attacks and information security threats, are of critical importance for the continuity of R&D activities in the field. Thanks to the R&D activities carried out, it is possible to lay the foundation for future technologies, forecasting and foresight studies (Kapletia et al., 2014; Maughan, 2010; Pawlicka et al., 2023). Quantum computing has the potential to exceed the limits of traditional computers and solve complex problems faster, so research in this field can shape future technologies and lead to innovation in many sectors (Preskill, 1998). Hence, it is crucial to closely follow relevant technologies and develop science and technology policies with the information obtained. A proactive science and technology policy can increase competitiveness at national and global levels and promote economic development (Jovane et al., 2008). The issue is also very important in terms of information distribution or sharing. Research funding has a structure that encourages knowledge sharing which can helps to develop cybersecurity applications and quantum computing techniques by creating a broader knowledge sharing network, as it will encourage experts working in these fields to share their knowledge and experiences. In the light of this information, seeking answers to questions such as which research institutions frequently fund research in the field of quantum computing, supercomputers and Cyber security, and how the performance of these research institutions is will contribute to identifying the dominant actors in the mentioned issues.

We took advantage of the SNA to find answers to these questions. The important indicators of the SNA of the first 25 institutions that stand out presented in a table. The Betweenness Centrality value is important as a metric that measures how much an institution affects communication within the network and how much it takes part in the shortest paths between other institutions (Brandes, 2001; Prountzos & Pingali, 2013). In this context, institutions with high betweenness centrality values can be considered as institutions that direct or control the communication flow of the network (Leydesdorff, 2007; Magaia et al., 2015). Particularly in areas such as cybersecurity and quantum computing, such institutions can play a vital role in ensuring the flow and security of critical information. According to our data, the institutions with the highest betweenness centrality values are: "DIRECT FOR COMPUTER & INFO SCIE & ENGINR," "OFFICE OF ADVANCED CYBERINFRASTRUCTURE (OAC)," "DIVISION OF COMPUTING AND COMMUNICATION FOUNDATIONS," "DOE OFFICE OF SCIENCE USER FACILITY [DE-AC02-06CH11357]," and "EXASCALE COMPUTING PROJECT [17-SC-20-SC]." These institutions can be considered important players in the network. On the other hand, the High Aggregate Constraints value is a metric that shows how frequently an institution interacts with other institutions within the network and how much connection constraints it has (Burt, 2002;

Saglietto et al., 2020). A high aggregate constraints value may indicate that an organization is heavily interconnected with many different parts of the network and therefore contributes to the integrity of the network. In fields such as cybersecurity and quantum computing, such institutions can facilitate integration and data flow between different subsystems. According to our data, the institutions with the highest aggregate constraints value are "DIRECT FOR COMPUTER & INFO SCIE & ENGINR," "OFFICE OF ADVANCED CYBERINFRASTRUCTURE (OAC)," "DIVISION OF COMPUTING AND COMMUNICATION FOUNDATIONS," "DOE OFFICE OF SCIENCE USER FACILITY [DE -AC02-06CH11357]," and "EXASCALE COMPUTING PROJECT [17-SC-20-SC]" institutions (Table 5). "NATIONAL SCIENCE FOUNDATION (NSF)," "NETHERLANDS ORGANIZATION FOR SCIENTIFIC RESEARCH (N.W.O.)," "NASA," can be cited among the funding institutions that are expected to increase value in research in critical areas such as cyber security and quantum computing in the future with low restriction levels. These institutions provide financial support to various projects in order to increase cyber security, improve computing capacities and shape the technologies of the future. NSF supports student education and the development of advanced computing infrastructures in cybersecurity and quantum computing, while N.W.O. and N.C.F., their organizations also promote scientific research and computing capabilities in the Netherlands. NASA funds projects in the fields of cyber security and computing in the context of space and information technologies. These institutions are institutions that should be followed closely as they show potential for development in Cyber security and quantum computing projects soon with low levels of restrictions. (Table 6)

Table 6: Funding Organization

All Degree	Betweenness centrality	High Aggregate constraints	Low Aggregate constraints
DIRECT FOR COMPUTER & INFO SCIE & ENGINR	DIRECT FOR COMPUTER & INFO SCIE & ENGINR	DIRECT FOR COMPUTER & INFO SCIE & ENGINR	NATURAL SCIENCE FOUNDATION OF HUNAN PROVINCE [14JJ3107]
OFFICE OF ADVANCED CYBERINFRASTRUCTURE (OAC)	OFFICE OF ADVANCED CYBERINFRASTRUCTURE (OAC)	OFFICE OF ADVANCED CYBERINFRASTRUCTURE (OAC)	NAVAL METEOROLOGY AND OCEANOGRAPHY COMMAND
DIVISION OF COMPUTING AND COMMUNICATION FOUNDATIONS	DIRECT FOR MATHEMATICAL & PHYSICAL SCIEN	NATIONAL SCIENCE FOUNDATION	NAVAL OCEANOGRAPHY OPERATIONS COMMAND
DIRECT FOR MATHEMATICAL & PHYSICAL SCIEN	DIRECT FOR BIOLOGICAL SCIENCES	DOE OFFICE OF SCIENCE USER FACILITY [DE-AC02-06CH11357]	NATIONAL SCIENCE FOUNDATION, INTEGRATIVE GRADUATE EDUCATION AND RESEARCH TRAINEESHIP [DGE 0903629]
DOE OFFICE OF SCIENCE USER FACILITY [DE-AC02-06CH11357]	DOE OFFICE OF SCIENCE USER FACILITY [DE-AC02-06CH11357]	STATE OF ILLINOIS	OFFICE OF ADVANCED CYBERINFRASTRUCTURE AWARD [OAC 1835612]
EXASCALE COMPUTING PROJECT [17-SC-20-SC]	EXASCALE COMPUTING PROJECT [17-SC-20-SC]	U.S. DEPARTMENT OF ENERGY, OFFICE OF SCIENCE [DE-AC02-06CH11357]	NATIONAL SCIENCE FOUNDATION, DIVISION OF MATERIALS RESEARCH [DMR 1409620]
U.S. DEPARTMENT OF ENERGY, OFFICE OF SCIENCE [DE-AC02-06CH11357]	DIVISION OF COMPUTING AND COMMUNICATION FOUNDATIONS	PROGRAM FOR GUANGDONG INTRODUCING INNOVATIVE AND ENTREPRENEURIAL TEAMS [2016ZT06D211]	NETHERLANDS ORGANIZATION FOR SCIENTIFIC RESEARCH (N.W.O.)
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN	NATIONAL SCIENCE FOUNDATION	CHINA SCHOLARSHIP COUNCIL	NETHERLANDS NATIONAL COMPUTING FACILITIES FOUNDATION (N.C.F.)
NATIONAL BIOMEDICAL COMPUTATION RESOURCE (NBCR)	ICER	DIRECT FOR MATHEMATICAL & PHYSICAL SCIEN	MULTIMEDIAN PROJECT
PROGRAM FOR GUANGDONG INTRODUCING INNOVATIVE AND ENTREPRENEURIAL TEAMS [2016ZT06D211]	U.S. DEPARTMENT OF ENERGY, OFFICE OF SCIENCE [DE-AC02-06CH11357]	UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN	NETHERLANDS FOUNDATION FOR SCIENTIFIC RESEARCH NWO
NATIONAL NUCLEAR SECURITY ADMINISTRATION	NATIONAL BIOMEDICAL COMPUTATION RESOURCE (NBCR)	NVIDIA	NATIONAL KEY RD PROGRAM [2018YFE0120800, 2017YFA0402603, 2018YFA0404504, 2018YFA9494691]
NVIDIA	UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN	DIVISION OF MATHEMATICAL SCIENCES	NATIONAL NATURAL SCIENCE FOUNDATION OF CHINA (NSFC) [11633004, 11975072, 11835009, 11890691, 12033008]
CHINA SCHOLARSHIP COUNCIL	STATE OF ILLINOIS	EXASCALE COMPUTING PROJECT [17-SC-20-SC]	NSF MRI (IBM BLUEGENE/L SUPERCOMPUTER') [CNS0421498, CNS-0420873, CNS-0420985]
NATIONAL SCIENCE FOUNDATION	PROGRAM FOR GUANGDONG INTRODUCING INNOVATIVE AND ENTREPRENEURIAL TEAMS [2016ZT06D211]	OFFICE OF SCIENCE OF THE U.S. DEPARTMENT OF ENERGY [DE-AC05-00OR22725]	NSF SPONSORSHIP OF THE NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
STATE OF ILLINOIS	NVIDIA	DIV OF CHEM, BIOENG, ENV, & TRANSP SYS	OCEANOGRAPHER OF THE NAVY
DIRECT FOR BIOLOGICAL SCIENCES	CHINA SCHOLARSHIP COUNCIL	DIVISION OF COMPUTING AND COMMUNICATION FOUNDATIONS	NSF-MRI (FRONT RANGE COMPUTING CONSORTIUM (FRCC) [CNS-0821794]
DIV OF CHEM, BIOENG, ENV, & TRANSP SYS	OFFICE OF SCIENCE OF THE U.S. DEPARTMENT OF ENERGY [DE-AC02-05CH11231]	DEPARTMENT OF ENERGY	NASA ADVANCED INFORMATION SYSTEMS TECHNOLOGY (AIST) PROGRAM

ICER	NASA HIGH-END COMPUTING (HEC) PROGRAM THROUGH THE NASA ADVANCED SUPERCOMPUTING (NAS) DIVISION AT AMES RESEARCH CENTER	U.S. DEPARTMENT OF ENERGY [DE-AC05-00OR22725]	NASA EARTH AND SPACE SCIENCE FELLOWSHIP
DEPARTMENT OF ENERGY	NATIONAL SCIENCE FOUNDATION [ACI-1053575]	NATIONAL BIOMEDICAL COMPUTATION RESOURCE (NBCR)	NASA ATMOSPHERIC COMPOSITION MODELING AND ANALYSIS PROGRAM (ACMAP)
DIRECT FOR COMPUTER & INFO SCIE & ENGINR [1440761] FUNDING SOURCE: NATIONAL SCIENCE FOUNDATION	OFFICE OF SCIENCE OF THE U.S. DEPARTMENT OF ENERGY [DE-AC05-00OR22725]	DIRECT FOR BIOLOGICAL SCIENCES	NATIONAL HUMAN GENOME RESEARCH INSTITUTE [HG006139, HG002536]
NOVA	U.S. DEPARTMENT OF ENERGY [DE-AC05-00OR22725]	ICER	NATIONAL INSTITUTE OF GENERAL MEDICAL SCIENCES [GM053275]
NWO VENI FELLOWSHIP	NATURAL SCIENCES AND ENGINEERING RESEARCH COUNCIL OF CANADA	DIRECT FOR COMPUTER & INFO SCIE & ENGINR [1440761] FUNDING SOURCE: NATIONAL SCIENCE FOUNDATION	NATIONAL SCIENCE FOUNDATION [DGE-0707424]
NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY	NATIONAL SCIENCE FOUNDATION [DMS-0456713, DMS-1025468]	DIVISION OF COMPUTER AND NETWORK SYSTEMS	NATIONAL NATURAL SCIENCE FOUNDATION OF CHINA [11775127]
NASA [NNX17AL74G]	OFFICE OF NAVAL RESEARCH [ONR DRI N0014-10-1-0554, N00014-11-1-0306]	NATIONAL KEY R&D PROJECT IN CHINA [2016YFB1000302]	NATIONAL KEY RESEARCH AND DEVELOPMENT PROGRAM [2020YFB1901700]
NETHERLANDS RESEARCH SCHOOL FOR ASTRONOMY, NOVA [NOVA5-NW3-10.3.5.14, NWA.1160.18.316]	DIRECT FOR COMPUTER & INFO SCIE & ENGINR [1440761] FUNDING SOURCE: NATIONAL SCIENCE FOUNDATION	OFFICE OF SCIENCE OF THE U.S. DEPARTMENT OF ENERGY [DE-AC02-05CH11231]	NUCLEAR POWER TECHNOLOGY INNOVATION CENTRE

Entropy Analysis

In information theory, entropy is a concept that measures the degree of uncertainty or predictability of a message or information (Gray, 2011; Vedral, 2002). This concept, developed by Claude Shannon, has great importance in the field of information theory (Shannon, 1948). Shannon entropy measures how random or unpredictable characters or symbols in a language are. So, a high entropy value indicates that the characters or symbols in a text are more random and unpredictable. In other words, entropy refers to the degree of disorganization of information in a text. A higher entropy value indicates more ambiguity and disorder in the text, indicating that the text has a more complex and diverse use of language. In the figure, the entropy values differ. While 1984 was the year with the lowest entropy value, it was observed that the highest entropy value was recorded in 2022. The total number of unique terms used in creating the image is 33252. In other words, it shows how wide the vocabulary used in the analysis of the data in the table is. When we examine the image in the light of this information, we see that entropy values increased in the late 1980s and early 1990s. This means that the complexity in the field increased during this period. While it was observed that entropy values continued to increase rapidly towards the mid-1990s, although entropy values continued to increase towards the early 2000s, it is observed that there were some fluctuations in this period. Starting from the early 2010s, entropy values started to increase again, and the increase continued until the early 2020s. This could be interpreted as indicating that the field is becoming increasingly complex and more diverse. Although entropy values have continued to increase since the early 2020s, the appearance that the rate of increase has begun to slow down slightly can be interpreted as field-oriented dynamics starting to mature. (Figure 6)

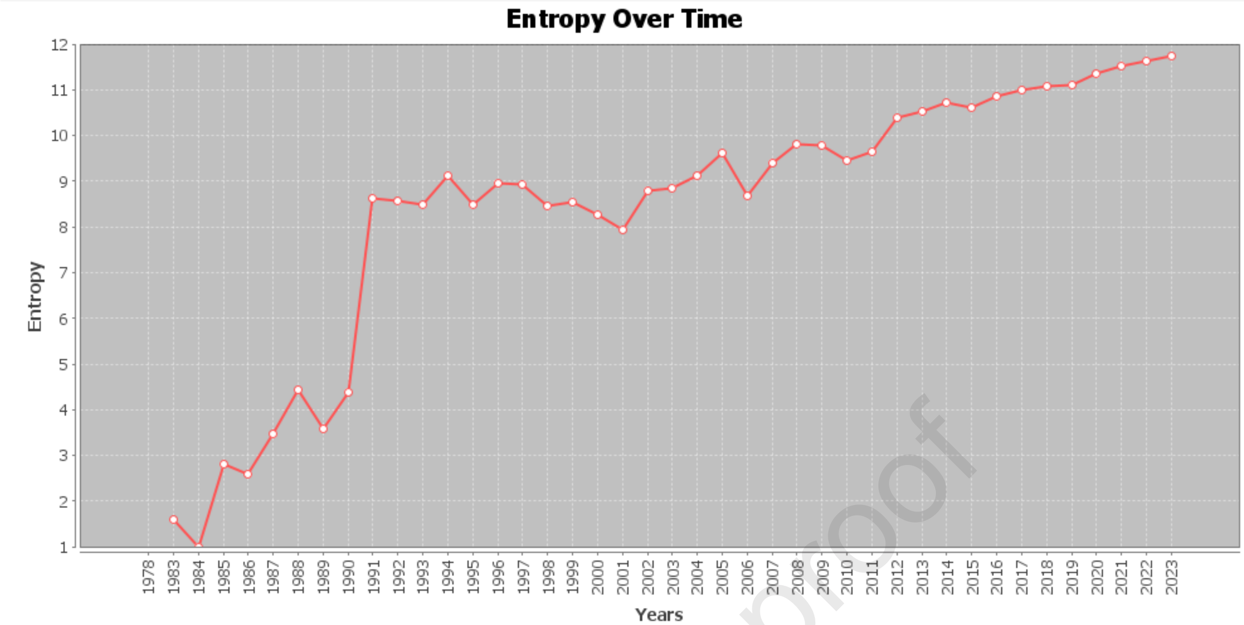

Figure 6: Entropy Over Time

Discussion

The study employs a technology mining approach, combining bibliometrics, social network analysis (SNA), and scientometrics to analyze the dynamics of quantum computing, supercomputers, and cyber security. The comprehensive method aims to reveal potential usage areas, advantages, disadvantages, technology saturation levels, and untapped domains in these subjects. The dataset, covering 1,774 documents from 791 sources over 1978-2023, indicates an annual growth rate of 11.25%. The average document age is 12.9 years, with each document cited an average of 15.51 times and containing 54,746 references.

The paper brings fresh insights into the intersections of quantum computing and supercomputing with cybersecurity. These findings are valuable not only for understanding current challenges and benefits but also for anticipating future developments. The keyword analysis effectively reveals critical aspects of the field. Notably, it identifies the pivotal role of keywords such as "MODEL," "ALGORITHM," and "SIMULATIONS" in quantum computing, emphasizing their critical contribution to algorithm development and system simulations. In cyber security, keywords like "PERFORMANCE" and "IDENTIFICATION" play a key role in identifying and monitoring cyber-attacks. Moreover, concepts such as "FLOW" and "TRANSPORT" are crucial for controlling network traffic, underscoring their vital role in cyber security implementation. The analysis reveals that these elements, with "High Aggregate constraints" values, significantly influence the fields of quantum computing and cyber security, providing valuable insights into the interconnected dynamics of these technologies. The study contributes by uncovering these intricate relationships and shedding light on novel perspectives for understanding and managing quantum computing, supercomputers, and cyber security. The study utilizes cluster analysis to visually present nine significant clusters that emerged, offering a comprehensive view of the interconnectedness and concentration of topics in scientific literature related to quantum computing, supercomputers, and cyber security. These clusters delve into diverse areas, including electronic structure code in cybersecurity, stochastic multi-cloud models, grip computing, efficient massive parallel computing techniques in cybersecurity, supercomputers' capabilities in addressing cybersecurity problems, and the potential impact of quantum computing on cryptography and cybersecurity.

Performance indicators and publication data reveal that journals like "COMPUTER PHYSICS COMMUNICATIONS" and "COMPUTER" hold the highest number of citations, emphasizing their influential contributions to the field. Additionally, journals such as "JOURNAL OF SUPERCOMPUTING" and "PARALLEL COMPUTING" emerge as leading sources, providing a valuable guide for researchers seeking current and impactful studies in quantum computing, supercomputers, and cyber security. These indicators not only contribute significantly to understanding the literature but also play a crucial role in identifying key sources and trends in technology and engineering management.

The study identifies key researchers and institutions in this field. Researchers such as Ulrich Ruede, Peter V. Coveney, and N. N. Smirnov stand out for their significant H-index and citation counts, indicating the wide-reaching impact of their work. Noteworthy institutions, including the University of Illinois, Oak Ridge National Laboratory, Harvard University, and the University of California, San Diego, are recognized for their influential research in these domains. The H-index values and citation counts underscore the substantial contributions of these authors, while prominent institutions like NASA, Lawrence Berkeley National Laboratory, and others play crucial roles in advancing space and energy technologies, supercomputers, and cyber security. The study highlights the global leadership of these institutions, both in the United States and worldwide, emphasizing their pivotal role in fostering progress in these cutting-edge technology areas.

The paper underscores the critical impact of research funding in advancing technology and engineering management, particularly in the realms of quantum computing, supercomputers, and cyber security. It highlights that such funding not only encourages technological development but also plays a vital role in addressing modern challenges, such as cyber threats. Social Network Analysis (SNA) is employed to identify key funding institutions, revealing entities like "DIRECT FOR COMPUTER & INFO SCIE & ENGINR" and "OFFICE OF ADVANCED CYBERINFRASTRUCTURE (OAC)" as central players, influencing communication flow and contributing to network integrity. Moreover, institutions with high Aggregate Constraints values, such as "NATIONAL SCIENCE FOUNDATION (NSF)" and "NASA," are identified as crucial supporters for future research in cybersecurity and quantum computing, signaling potential development with low restrictions. The study emphasizes the significance of closely monitoring these institutions for their contributions to critical technology areas.

Findings from the entropy analysis reveal the evolving complexity and diversity in the field over time. Entropy values, representing the unpredictability of characters or symbols in text, indicate increased complexity from the late 1980s to the early 2020s. The lowest entropy in 1984 and the highest in 2022 signify fluctuations and a gradual slowdown in the rate of increase, suggesting maturation in field-oriented dynamics. The study suggests that the evolving entropy values reflect the field's transition into a more complex and diverse state, with recent trends indicating a potential maturing phase.

Conclusions, Limitations and Future Research

The key conclusions can be summarized as follows:

1. Research focuses on model and algorithm development for performance analysis as seen in the keyword analysis shown in Table 1 and Figure 2.
2. Cluster analysis shown in Figure 3 and Table 2 provides further detail on the research groups. While computing and modeling heavy topics such as electronic structure code, stochastic multicloud model, efficient massive parallel, and supercomputing system come out as groups, we also see grid computing and energy efficiency as application area groups.
3. Source analysis shown in Figures 4 and 5, Table 3, 4, 5 and 6 indicate research is done and published in computing heavy sources and led by United States.
4. Entropy analysis shown in Figure 6 shows that the area has attracted high interest and developing into a complex state.

These findings underscore the significance of this research field, emphasizing its broad and rich scope covering leading topics like cybersecurity, supercomputers, and quantum computing. The analysis suggests rapid developments in these areas with the potential to significantly impact future cybersecurity strategies. The following are the key contributions of this study:

1. The results contribute to the literature by highlighting the underlying constructs of research in supercomputers and quantum computing in the area of cybersecurity.
2. These results also serve the industry and government to identify research partners and research gaps.
3. The framework developed to analyze the research landscape in this case can easily be used to analyze other areas of research.

The research has several limitations. The conclusions are drawn from the analysis of published articles. Further case analyses on site would help validate the findings. An expert panel may also help highlight findings which were not captured well.

A technology assessment and roadmapping effort to identify key technology and research gaps may follow this study as well.

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Exploring research landscape in quantum computing regarding cybersecurity

Quantum computing for cybersecurity

Bibliometric analysis to identify research leaders

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authors