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Quantum clustering drives innovations: A bibliometric and patentometric analysis

Shradha Deshmukh
shradha.deshmukh.phd2020@sitpune.edu.in

Preeti Mulay
Symbiosis Institute of Technology (SIT), Symbiosis International (Deemed University) (SIU), Pune, India

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Quantum clustering drives innovations: A bibliometric and patentometric analysis

Shradha Deshmukh, Preeti Mulay

Symbiosis Institute of Technology, Symbiosis International (Deemed University), Pune, India.

Shradha.deshmukh.phd2020@sitpune.edu.in, preeti.mulay@sitpune.edu.in

Abstract

The paper presents a bibliometric analysis from 2014 to 2020 of the emerging and engaging field of quantum computing called Quantum Machine Learning (QML). The study discusses the analysis results from the comprehensive high indexed databases worldwide such as Institute of Electrical and Electronics Engineers (IEEE), Scopus, Web of Science (WOS), Google Scholar and the Association for Computing Machinery (ACM). Tools like iMapbuilder, IBM and SPSS Statistics are used to provide meaningful insights and flawless representations of the extracted data. There has been little research to provide a macroscopic overview of renowned authors, subject areas, funding agencies and patent applications related to Quantum Clustering (QC). The result and analysis of this study show an interesting fact, most researchers are now aware of quantum technology from the past few years. The purpose of bibliometric and patentometric analysis papers is to figure out the importance and utility of the QC research area. Most of the countries are taking an initiative to seek attention towards QC but the analysis shows that China and the US are leading. The survey revealed that the maximum numbers of publications of QC are from Physics and Astronomy followed by Computer Science.

Keywords: Quantum Machine Learning, Quantum Clustering, Bibliometric, Patentometric, Quantum Computing

Introduction

Clustering is the process of grouping data points by creating partitions based on similarity. When two data points are similar in some manner, often they share the same characteristics. The ultimate prediction is the set of clusters themselves. This technique works only with data in numeric form. This goes on to show us that only categorical variables need to be converted to numeric variables by binarization. There are various clustering methods to predict these similarities. The types of clustering methods are connectivity-based, centroid-based, density-based and distribution-based. Let's look at the first method.

Centroid-Based Clustering:- The centroid based clustering uses a centroid to represent each cluster which is derived by calculating the distance between the data points and the initial centroid of the cluster. Most widely used centroid based algorithm is the K-means algorithm. In K-means, centroids are randomly placed and iterations are stopped when the centroid finds the shortest sum of the distances from the point to the centre. K-means helps to minimize the aggregate intra-cluster distance.

Connectivity-Based Clustering:- In this method, the cluster is grouped with the nearest neighbour which is based on the distance between the data points. The important aspect is that one cluster is connected to another cluster to form a hierarchy. Connectivity clustering works in two ways,

1. Agglomerative:- or the ‘bottom-up approach’, initializes the mini-cluster and every iteration combines two small clusters to form a larger cluster.
2. Divisive:- or the ‘top-down approach’ starts from the biggest cluster and each iteration divides the bigger cluster into two smaller clusters.

Distribution-Based Clustering:- This is an interesting clustering method. The idea is that the data points are divided based on the probability of belonging to the same normal distribution. The distribution-based method is similar to centroid based clustering, except that distribution-based clustering uses probability to compute the clusters rather than using the mean. The user needs to define the number of clusters. For optimizing the clusters the distribution method goes through an iterative process. ‘Expectations maximization’ is one of the popular algorithms which use normal distribution for clustering.

Density-Based Clustering:- This method begins by searching for areas of dense data points and assigns those areas to the same clusters. The density of the clustering is defined by the concentration of the data points that fall in a certain threshold distance. The concentration of data points is called a cluster. There are parts where these clusters are separated by empty and sparse areas, such parts are labelled as noise. In most clustering methods, one needs to supply the number of clusters. To achieve this, using an approximation method to estimate the number of clusters is recommended, one such approximation method is the elbow method. Clustering algorithms are always sensitive to outliers. For eg., When an online user searches a product on Google or Amazon, they are presented with either the link to the product or other products that might be relevant to their search by the means of clustering. All the methods eventually boil down to the basic idea of wanting to find groups of similar objects.

Quantum computing has various advantages in optimization. This is why the researchers put forward to combine two different fields i.e. quantum technology and a learning algorithm hoping to introduce the benefits of quantum computing. The new type of clustering algorithm with quantum theory is the QC algorithm. The QC algorithm has peeked interests of researchers and has provided extensive results throughout a plethora of fields such as Computer Science, Physics, Astronomy, Engineering and Mathematics. Figure1 represents the top fields with the applicability of the QC algorithm.

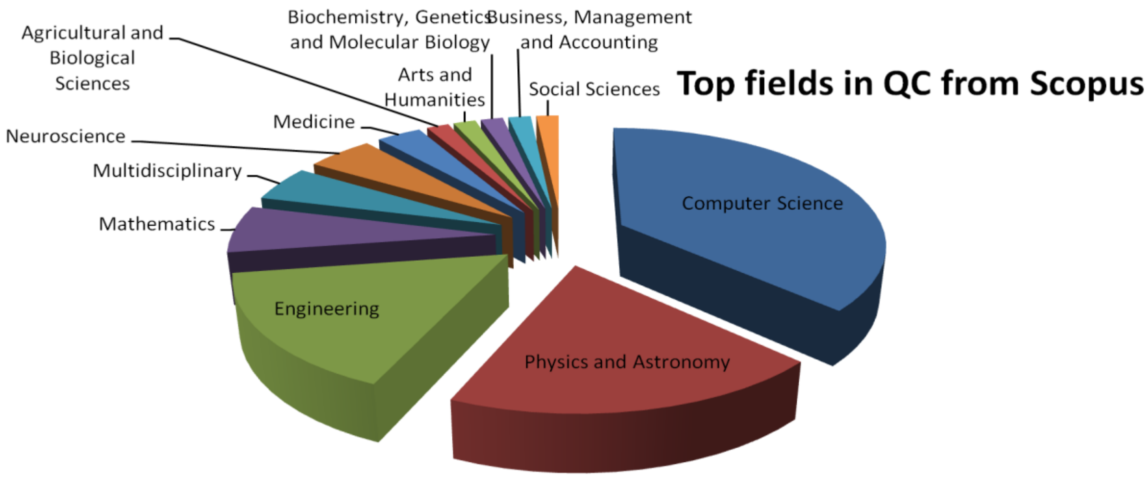


Figure1: Pie chart represents the top fields in quantum clustering. Data is fetched from the Scopus database and Web of Science database (2nd Dec)

Following the core idea of QC algorithm, it is divided into two categories, namely 'based on quantum optimization' or 'inspired by quantum mechanics'. Getting a concept from evolutionary scheme author [1] proposed a new algorithm. To find the targeted area's optimal solution the proposed quantum algorithm uses evolutionary strategies, it reduces dependencies on the initial cluster to update the clustering centre. Another QC algorithm is introduced by the author [2] which is based on the theory of quantum mechanics. Gradient descent optimization technique is used to find the clustering centre and to calculate the min of potential energy. Author [3] illustrates the physical basis of QC, determining gradient descent and Schrodinger's equation.

Related work and bibliometric analysis

As stated by the different philosophies, dozens of research papers are published on the new and overwhelmingly impressive QML. Observe the general characteristics of the QML which describes the number of approaches and summarizes the observations using a mind-map in Figure1. Almost all the quantum algorithms are depending on the application of Grover's search algorithm which includes the different unsupervised learning methods such as hierarchical clustering, quantum random access memory, quantum principal component analysis, quantum k-means and quantum k-medians. Additionally, QML includes adiabatic quantum computing, quantum classification and quantum pattern recognition. Also, Quantum information processing (QIP) and machine learning (ML) together are emerging fruitfully. In this[7] paper, we are deeply involved in drawing on the QIP techniques. A huge amount of data is generated nowadays making it essential to have an efficient clustering algorithm that can be helpful in demanding areas such as Web Mining, Astronomy and Bioinformatics.

Quantum Random Access Memory (QRAM) is used to store quantum states and it can be queried with the superposition principle [8]. Kernel matrix and calculation of dot product rely on the quantum random access memory structure. The concepts mentioned above are not only for unsupervised learning, they are also relevant to the Quantum Support Vector Machine (QSVM) with exponential speedup [8]. The quantum k-means unsupervised learning algorithm has two input states i.e. quantum and classical, both are essential and dependent on the QRAM. The k-median algorithm merges different concepts and achieves exponential speedup with the help of Grover's search algorithm. Hierarchical clustering can also follow this approach.

Author [9] states that the QRAM is an array wherein every cell has a unique numerical address that allows addressing memory cells in a classical computer. QRAM has the two registers i.e. input and output, both are composed of qubits. Input register addresses the cell and the output register returns the stored information. The quantum context principle component analysis (QPCA) relies on the Eigen decomposition of the matrix. The hamiltonian task helps QPCA achieve exponential speedup additionally providing the input and output quantum states.

Author [10] says that Grover's search algorithm is for almost every QC algorithm. When compared to classical counterparts, the QC algorithms offer speed but they don't improve the quality of algorithms. The simple version of a quantum k-means uses Grover's search algorithm to catch the nearest data points. K-means algorithm initially finds centroids and assigns vectors to the closest centroid[11]. Quantum hierarchical clustering and Quantum k-median both follow the same concepts to form a cluster. The purpose of the hierarchical clustering algorithm isn't finding a median of the points, the quantum algorithm focuses on calculating the largest distance between the two data points in a cluster. The quantum version and classical version have a similar problem of divisive clustering. The algorithm performs well if the clusters are separated and balanced.

This is all about QC brief introduction and developments. To dive deeper into the QC research area, a bibliometric analysis of the QC is needed. This paper showcases the bibliometric study and highlights the QC related fields.

Need for bibliometric and patentometric analysis

The bibliometric and potentiometric analysis helps the readers locate research gaps effectively and gives a glimpse of the intended field. Sometimes the analysis targets a specific timeline or covers all the revolutions related to the field. The term was introduced by Alan Pritchard (1969) who also stated its applications are apropos throughout the streams that are interested in exploring this field. Introducing the potential researcher with emerging QC applicability is the reason why we performed the quantitative analysis. As more and more research analysts are aware of the framework and the crucial concepts related to QC, it is becoming a vast field that has numerous prospects to work with. Pitter Wittek [1] provides the first attempt at a survey on QML algorithms. In it, he mentions a major overview of QML till 2014 with up-to-date information including the challenges and opportunities in QC. He also highlights the QML algorithms with hardware and software challenges with a systematic review. Another seminal survey[8], provides an in-depth review of the field of QC in a tabular format with exciting comparative analysis of platform trends, it also highlights other researcher's previous works year-wise. We observed that no author provides bibliometric and patentometric analysis details about applicable subject areas, top researching countries, top publishing authors and affiliation details.

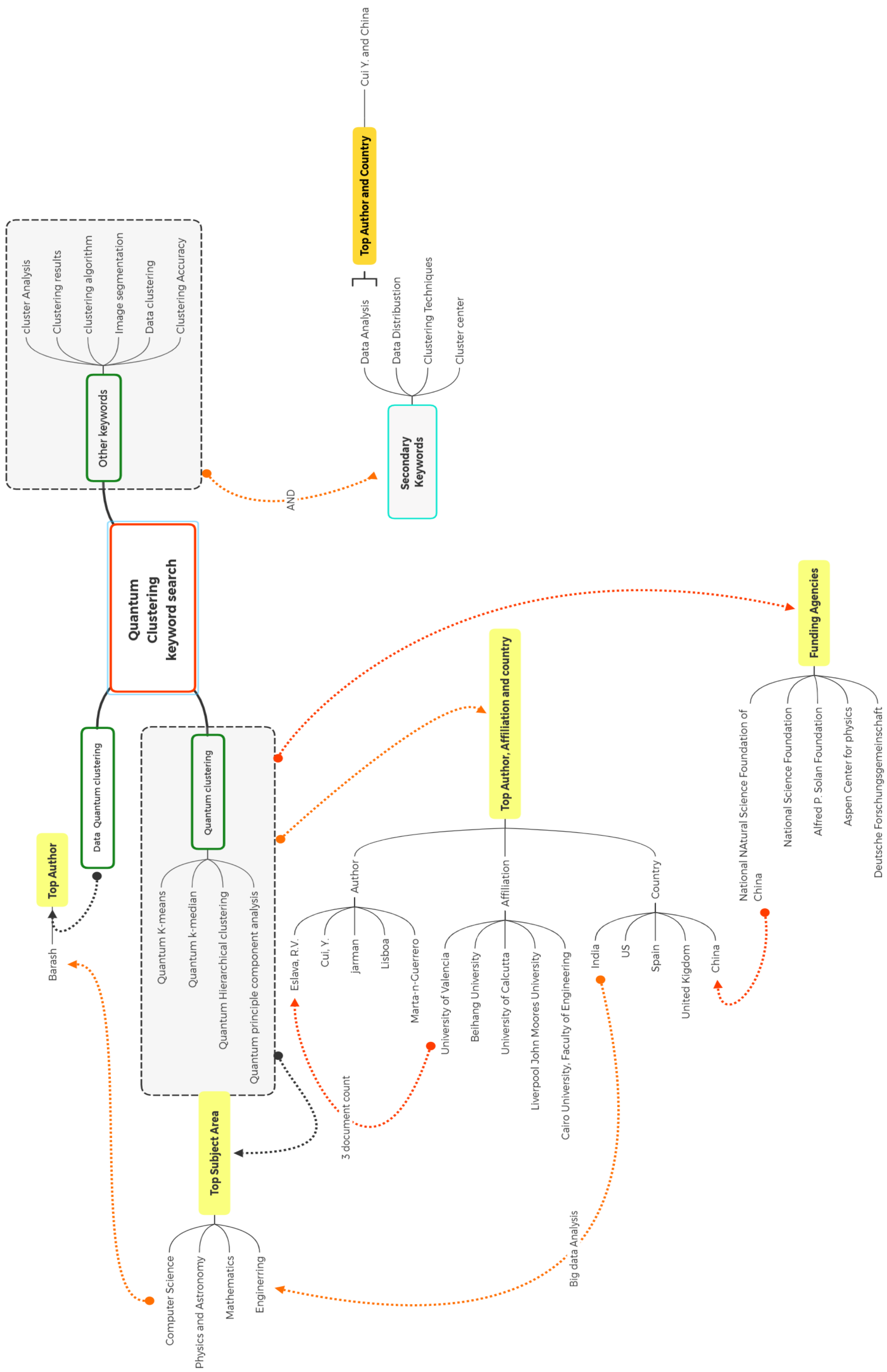


Figure 2: Mind map overview summarizing the keyword search data

Designing the keyword search strings

The central thought behind drafting this paper is to identify and highlight the relevant work in the QC research area. For that, we use different keywords related to QC and run a systematic keyword search. Figure2 depicts a pictorial representation of keywords summary in the form of a mind map. The mind map approach is used to showcase the various relationships'. The primary and secondary keywords associated with QC are used together. For the whole analysis, four keyword search strings are used in Table1. The results from each query pattern are summarized in the mind map. In the mind map, primary keywords are related to QC and use a conjunction to highlight the secondary keywords. Arrows are used, to show the established mapping between keywords. In Figure2, the mind map summarizes the search query pattern in pictorial form. It showcases the top authors, top countries, leading affiliations and the subject areas all associated with QC. Table1 showcases, a total of four query searches on the different databases that are used to refine the most relevant search for QC.

A keyword search was conducted on account of the following observations:

1. Initially, keywords had overlapping meaning.
2. As database key searching was common and acronyms were used to run keyword searches, non-relevant papers and articles made their way in the results making them irregular. This anomaly occurred as acronyms have different meanings in different streams.
3. To get a maximum list of relevant information non-overlapping keywords are essential. This enables the end-user to fetch research data from QML world.
4. Keyword selection is crucial and it can lead to finding related algorithms or mathematical models.

Table1: Keyword search by various databases from 2014-2020 (4th Dec 2020)

Query	**Databases**					
	Scopus	**WOS**	**IEEE**	**Google Scholar**	**Science Direct**	**ACM**
"Quantum Clustering"	37	25	12	478	186	2
"Quantum Machine learning" AND "Clustering"	118	98	29	848	230	31
"Data Quantum Clustering"	1	0	1	0	0	0
"Quantum Computing" OR "Quantum Machine Learning" AND "Quantum Clustering"	34	3	2628	76	2744	1117

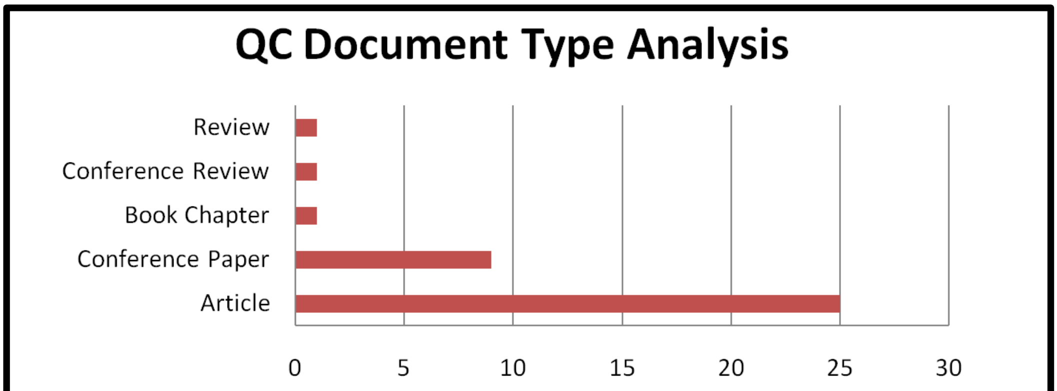
Table2 displays paper count per year across several databases available for researchers. It is evident from the table that the most widely used database is Scopus and it has seen a consistent increase in the number of publications from 2014 to 2019. The number of publication increased almost 10 fold in a short span of 5 years. At its peak in 2019, it had 51 papers although the current trend does suggest a fall in the number of publications. Similarly, we also have WOS and IEEE database and apart from 2015 when there were no papers in WOS we have seen a single-digit increase in the number of papers being published.

Table2: Per year paper count for 'Quantum Clustering' keyword from Scopus, WOS and IEEE (4th Dec 2020)

Year	**Scopus Document count**	**WOS Document count**	**IEEE**
2014	5	2	1
2015	7	0	0
2016	8	6	2

2017	19	4	0
2018	29	5	3
2019	51	5	0
2020	31	4	3

Figure3 (below) shows us type of document and its maximum number of papers available in the database. From Figure3 it is evident that the article category of the document has a maximum number with 25. Next thing that comes close to the article category is the conference paper category coming close to 10. Later, we have book chapters, conference reviews and review papers counting below 5 each.



	Article	Conference Paper	Book Chapter	Conference Review	Review
Series1	25	9	1	1	1

Figure3: Bar chart shows the QC document type from the Scopus database (7th Dec 2020)

Figure4 talks about available data on Scopus for QC. This will provide a bibliometric analysis performed on the data. QC is a trending topic worldwide and this can be observed from the map below which shows that the research is being carried out worldwide. Several countries, especially in Asia and Europe are heavily involved.

Figure4: Top countries working on Quantum Clustering (10th Dec 2020)

The Table3 displayed below showcases authors, their country of origin, their number of documents available on Scopus and a timeframe of their published work.

Eslava R, author from the US has 6 documents available on QC and was active between 2017-19. We have Cui, Yi and Jarman from China and Canada respectively with 5 papers each available on Scopus. Notably, Cui, Yi worked more recently from 2016-2020 and Jarman between 2014-2019. Lisboa from the UK has 4 publications, same as Marta-n-Guerrero

Table3: Top 10 Authors in QC fetched from the Scopus database (10th Dec 2020)

Sr. No.	Author Name	Country	Year of publications	Document count in Scopus
1	Eslava,R.	US	2017-2019	6
2	Cui, Yi	China	2016-2020	5
3	Jarman	Canada	2014-2019	5

4	Lisboa	UK	2014-2019	4
5	Marta-n-Guerrero	Spain	2018-2020	4

Table4 shows us authors, their titles, and the number of times when their title got citied. Paper with the source title ‘Measurement: journal of the International Measurement Confederation’ got cited 15 times. There are a couple of papers with the source title ‘Neurocomputing’ submitted by various authors which got cited several times.

Table4: Highly cited papers in Quantum clustering fetched from the Scopus database (9th Dec 2020)

Authors	**Title**	**Year**	**Source title**	**Cited by**
Cui Y., Shi J., Wang Z. [26]	“Analog circuit fault diagnosis based on Quantum Clustering-based Multi-valued Quantum Fuzzification Decision Tree (QC-MQFDT)”	2016	Measurement: Journal of the International Measurement Confederation	15
Cui Y., Shi J., Wang Z. [27]	“Lazy Quantum clustering induced radial basis function networks (LQC-RBFN) with effective centre selection and radii determination”	2016	Neurocomputing	8
Li Y., Wang Y., Wang Y., Jiao L., Liu Y. [28]	“Quantum clustering using kernel entropy component analysis”	2016	Neurocomputing	7
Casa-Eslava R.V., Jarman I.H., Lisboa P.J.G., MartÃn-Guerrero J.D. [29]	“Quantum clustering in non-spherical data distributions: Finding a suitable number of clusters”	2017	Neurocomputing	6
Shaikh T.A., Ali R. [30]	“Quantum computing in big data analytics: A survey”	2017	Proceedings - 2016 16th IEEE International Conference on Computer and Information Technology, CIT 2016, 2016 6th International Symposium on Cloud and Service Computing, IEEE SC2 2016 and 2016 International Symposium on Security and Privacy in Social Networks and Big Data,	5

			SocialSec 2016	
Liu D., Jiang M., Yang X., Li H. [31]	"Analyzing documents with Quantum Clustering: A novel pattern recognition algorithm based on quantum mechanics"	2016	Pattern Recognition Letters	5
Weinstein M., Heifetz A., Klann R. [32]	"Detection of nuclear sources in search survey using dynamic quantum clustering of gamma-ray spectral data"	2014	European Physical Journal Plus	5
Roche K.E., Weinstein M., Dunwoodie L.J., Poehlman W.L., Feltus F.A. [33]	"Sorting Five Human Tumor Types Reveals Specific Biomarkers and Background Classification Genes"	2018	Scientific Reports	3
Deutsch L., Horn D. [34]	"The Weight-Shape decomposition of density estimates: A framework for clustering and image analysis algorithms"	2018	Pattern Recognition	3
Hamdi N., Auhmani K., Hassani M.M. [35]	"A new approach based on quantum clustering and wavelet transform for breast cancer classification: Comparative study"	2015	International Journal of Electrical and Computer Engineering	3

Table5 shows the top sources for publications in QC which will help new researchers find recent and imminent work. The publication source titles are fetched from the WOS database because it has the most number of citations. The Neurocomputing source title has the highest number of citations i.e. 21. As shown in Table4, the top author in QC i.e. Cui, Li Y. and Eslava has their work published in Neurocomputing.

Table5: Top sources for publication in QC fetch from WoS database (12th Dec 2020)

SOURCE TITLE	Document count 2014-2020	Citation count
Neurocomputing	3	21
European Physical Journal Plus	2	4
Advances In Intelligent Systems And Computing	1	2
Applied Radiation And Isotopes	1	0
Heliyon	1	2
IEEE Access	1	0
IEEE Transactions On Neural Networks And Learning Systems	1	2

The table below, Table6, is a combination of two tables. One contains aspects such as funding agencies, document count and country of origin while the other contains affiliations and document counts. The purpose of Table6 is to state a correlation amongst all the aspects mentioned above. We can see that there are a couple of universities such as the University of Valencia, Beihang University, University of Calcutta and Liverpool John Moores University with 3 documents available on Scopus. Similarly, the National Natural Science Foundation of China agency has the maximum number of 6 documents. China's single funding agency has 6 documents whereas the US has 4 documents distributed amongst multiple funders. Table6 displays the Scopus data of the countries and the fundings they provide. With QC's rising significance and importance, it is evident that many countries are trying to hop the QC bandwagon. Funding such projects/researches will help these countries find their applications early on. It is quite evident from the pie chart that China is the leading investor with almost 44% of total funded projects across the globe. That's a significant percentage, especially for only one country. The second-largest investing country after China would be the US with an amount of almost 33% of total projects. These 2 giants combined form 77% projects, that are more than ¾ of the total global projects. We do have nations like Germany, Spain, Canada and the EU making up other ¼ of the equation.

Table6: Top 5 funding agencies with document count and Top 5 affiliation with document count fetch from the Scopus database (12th Dec 2020)

Funding Agencies	**Document count**	**Country**	**Affiliation**	**Document Count**
National Natural Science Foundation of China	6	China	University of Valencia	3
National Science Foundation	2	US	Beihang University	3
Alfred P. Sloan Foundation	1	US	University of Calcutta	3
Aspen Center for Physics	1	US	Liverpool John Moores University	3
Deutsche Forschungsgemeinschaft	1	Germany	Cairo University, Faculty of Engineering	2

Patenting Activity

A lot of research has begun lately and we have seen an influx in the number of patents [16-18]. This in turn has seen an increase in the revenue by almost $100billion in 53 years [19]. A big jump has occurred in revenue in the last couple of decades where it soared from $15 million in 1990 to $100 billion in 2000.[20] This has created a belief amongst the researchers that a patent can be a good source of income while safeguarding inventions from a legal perspective.[21][22] Big Industries and firms no more rely on in-house research as the problems get complex and high-tech each day. They have to explore additional options to boost work or increase the rate of developments. This makes firms explore external technologies widely referred to as open innovation.[23][24]

Table7 (below) provides the information on Query results from various databases available right from freepatentsonline.com to Google patent. For review purposes, we have considered 6 databases namely Espacenet, Freepatentsonline.com, Patent Scope, United States Patent and Trademark Office (USPTO), Indian Patent Advanced Search System (inPASS) and Google Patent. From this table, it is quite evident that the maximum number of query results are found on Freepatentsonline.com. The query ‘"Quantum Computing" OR "Quantum Machine Learning" AND "Quantum Clustering"’ returns a staggering 6639 results. The same query fetches only 208 results in Espacenet. "Quantum Clustering" query results in 111 hits on Freepatentsonline.com, 30 on Espacenet, 19 on Patent Scope and 30 on Google patent. Google has a maximum number of fetches for ‘"Quantum" AND "Incremental Learning"’, 38 counts. The same query returns the highest count on Patent Scope of 54 and 24 on USPTO. The query ‘"Quantum Incremental Learning"’ unfortunately doesn't fetch anything on any databases under review.

Table7: Patent document count from the various databases using different queries (2nd Jan 2020)

Query	**Databases**					
	Espacenet	***Freepatentsonline.com***	***Patent scope***	***US state Patent and Trademark Office(USPTO)***	***Indian patent advances search system(inPASS)***	***Google patent***

"Quantum Clustering"	30	111	19	11	0	30
"Quantum Machine learning" AND "Clustering"	9	1	26	0	0	15
"Data Quantum Clustering"	1	4	2	0	0	3
"Quantum Incremental Learning"	0	0	0	0	0	0
"Quantum" AND "Incremental Learning"	38	68	54	24	0	38
"Quantum Computing" OR "Quantum Machine Learning" AND "Quantum Clustering"	208	6639	0	4	0	4

Table8 represents countries, the number of patent applications and assignees for the same. China has the maximum number of patent applications with 21. It is followed by the US with 7. World Intellectual Property Organization (WIPO) has 4 patent applications while European Patent and South Korea each have 1.

Table8: Top patent application countries fetch from Google patent database (9th Dec 2020)

Country	Patent application count	Assignees

World Intellectual Property Organisation (WIPO)	4	Univ Ramot, David Horn, Assaf Gottlieb, Inon Axel, Reputation.com
US	7	David Horn, Michael Benjamin, Microsoft Technology Licensing, Brian Golbere
European Patent	1	Google, Inc.

Data construction

This study helps us understand the various steps required to get patents. There are two important aspects of it, patent assignment information and patent bibliographies. Patent bibliographies contain International patent classification (IPCs) and applicant's name, this can be extracted from multiple patent databases available online. The applicant name is registered following a standardised approach by using a combination of lower and upper case letters and excluding any spaces and punctuations. The number of utility patents granted is counted and measured for each applicant. The patent is considered high-quality if it has more number of citations. The patent office issues the assigned patent with the detailed information of acquisition describing the conveyance text, patent number, agreement details with the exact date and the principal information for patent right transfer. Based on the experience of the outside firm related to the patent acquisition, applicant names that are granted patents and buyers are matched together to understand and evaluate patent production activities. These patents provide exclusive rights to inventors and patent applicants. Due to this arises the need to segregate and analyze granted patents to identify its source whether it's from within or outside. From starting the process of filing a patent to patent getting accepted and granted the entire process requires a good chunk of time. With the complexity of the patenting process and its parameters surrounding it, we have considered only time-frame of 2010-2020.

Table9: Patent project data fetch from various patent database

Title	**Publication No.**	**Publication Date**	**Inventor(s)**	**International Classification**	**Cooperative patent Classification**	**Application No.**	**Date of Application**
"Adversarial quantum Machine Learning" [36]	US 2018 / 0349605 A1	06-12-2018	Nathan O. Wiebe, Redmond, WA (US), Ram Shankar Siva Kumar, Kirkland, WA (US	G06F 21 / 56 GOON 99 / 00 (2006 . 01) (2006 . 01	GO6F 21 / 566 (2013 . 01) ; G06N 99 / 005 (2013 . 01) ; GO6N 99 / 002 (2013 . 01)	15 / 624 , 651	15-01-2017
"Method and Apparatus for quantum clustering" [37]	WOO2/O93810	26-01 2010	David Horn, Tel Aviv (IL); Assaf Gottlieb, Hod HaSharon (IL);	G06F 7/30 (2006.01)	707/18, 707/100, 101, 102: 324/306: 708/400; 709/201; 712/14; 382/260	10/474,508	14-05-2002
"Quantum assisted optimization" [38]	W02017/189052 A1	02-11-2017	Delchev, Vasil S. California(US), Mohseni,	G06N 99/00(2010.01)	62/327, 384	PCT/US2016/069381	30-12-2016

			Masoud California (US)				
"Computer system and method for indexing and retrieval of partially specified type-less semi-infinite information" [39]	WO 2019/203718 A1	24-10-2019	SUNDSTROM, Mikael; Nilsanders vagen Lulea (SE)	G06F 16/31 (2019.01) G06F 16/35 (2019.01) HOLM (SE). G06F 16/2452 (2019.01) G06K 9/62 (2006.01)		PCT/SE2019/050354	17-04-2019

Preliminary Result

This study will prove more effective to understand the overall concepts behind the filed and granted patents in the fields related to QC. Various biographies or collections of databases related to patents are queried in Table2 which provides detailed analysis of keyword search for paper count using Scopus, WOS, IEEE, Google scholar, Sciencedirect database. The result presented in Figure5 shows an initial count obtained by the different query search. It was observed that the search results included duplicates until after applying filters for only articles and review papers for QC. Later we refined our query search to focus on recent research from the year 2014-2020. After taking insights from results, PRISMA[25] methodology was applied to fine-tune the search. This has helped in filtering the required information that is within the scope of the study and filtering out the irrelevant ones.

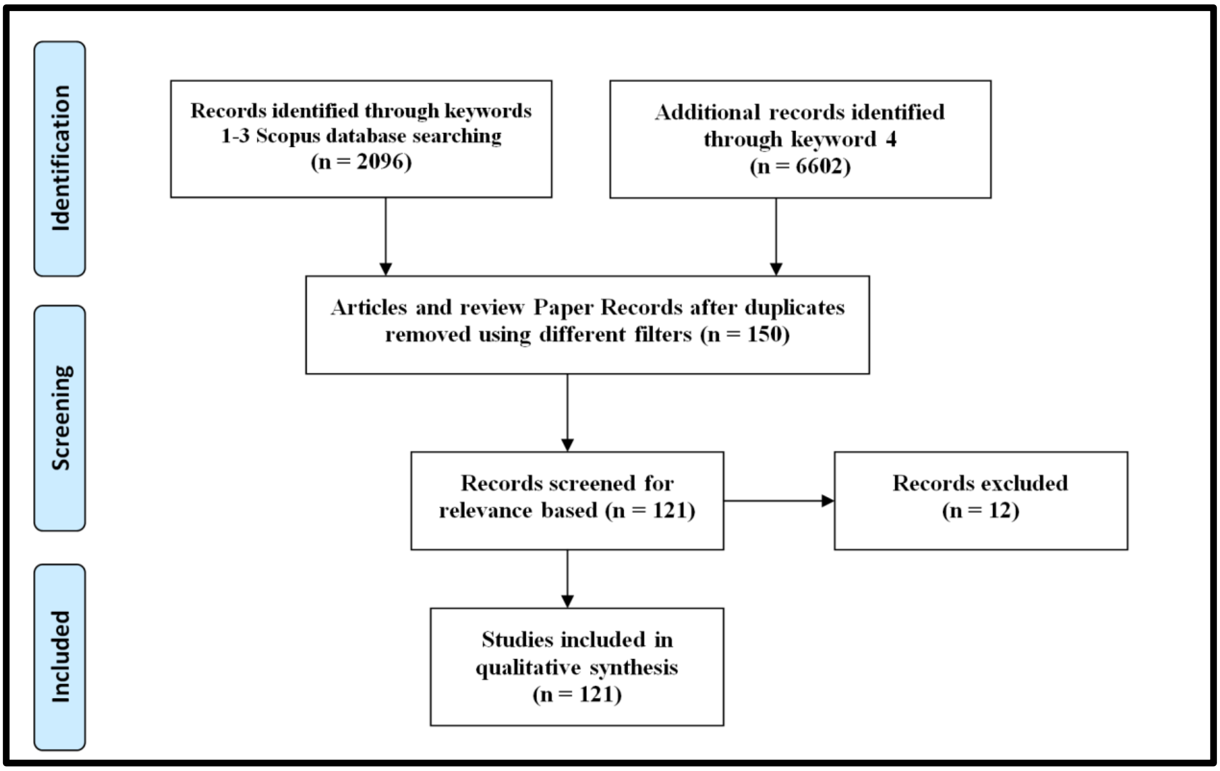


Figure5: Showing relevant papers using PRISMA flowchart. Adapted from [25]

PRISMA Flowchart

PRISMA is an acronym for (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). This is primarily used to index and provide better results for the Scopus search. [25] has performed extensive studies on how reporting systematic reviews worked earlier. This helped them summarize guidelines for future systematic review studies. PRISMA statement that is available on their official website contains a 27-item checklist and four-phase flow diagram helping authors on their projects. Currently, we adapt these diagrams and refine them based on the needs and in future, we wish to adapt it for a systematic review of QC.

Conclusion and Future Directions

We present a bibliometric analysis of the work done in the area of QC. Specially, we are focusing on an analysis of the 2014-2020 period for journal articles published in the area of QC. The reason behind selecting these specific six years is because during this stipulated period researchers were quite active and interested in the work of QC. It can also be called a peak period in the era of QC research. The paper count has shown a trend of focus shifting towards QC, this is backed up by the fact that the number of paper counts in 2019 was more than that of 2017. From the above facts, it is evident that China provides humungous funding to research more into the field of QC. This can be backed by numbers and authors like Cui and Jarman contributing five papers to QC study. Cui from China has the highest number of citations, fifteen for analogue circuit fault diagnosis. She has been contributing from 2016 in this field. Her second most cited paper is ‘Lazy quantum clustering induced radial basis function network’ which has eight citations. Neuro computing is also widely looked at and explored as it has 3 documents available from 2014-2020 and has been cited a total twenty one times, whereas articles and papers can date back before 2014. China has a maximum number of the patent application of twenty one which is almost three times more than that of the US. This shows that China is exploring options in QC for the next breakthrough. Query results for "Quantum Computing" OR "Quantum Machine Learning" AND "Quantum Clustering" return 6639 hits on Freepatentsonline.com and 208 on Espacenet which is maximum in both the case. Whereas "Quantum" AND "Incremental Learning" query fetches only 54 in Patent Scope and 38 in Google Patent which is maximum in their respective database. After an extensive survey, we felt the need to go through the patent databases in addition to research databases to streamline the future researches in the areas related to QC and hence this paper is presented. This paper depicts patentometrics which is an amalgamation of bibliometric and patent's analysis together. The scope of this paper includes research contributions from the past 15 years.

- The new quantum algorithm requires understanding and study of exponential numbers of bits for expanding the horizon on a full solution from the existing quantum algorithm. Due to this application of QML algorithm becomes infeasible

- As per existing studies, the exact requirement for the number of gates for QML algorithm is still unknown. Despite this fact, it will offer a colossal advantage for solutions to complex problems. The exact crossover point is yet to be determined.

- QML is more effective in clustering compared to Classical Machine Learning. The researcher can further study on how to overcome the lack of quantum hierarchical clustering and quantum incremental learning algorithms.

- QC, using fixed distance, has limitations in terms of learning iterations, distance matrix and execution time.

- Classical hierarchical clustering cannot extract historic data from older loops, Researchers can use the principle of minimum cluster centroids distance to replace the principle of the minimum data points distance. It has a better impact on clustering compared to classical technique. This alternative strategy is prone to errors.

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