CAPITAL UNIVERSITY OF SCIENCE AND TECHNOLOGY, ISLAMABAD

Evaluation Of Researchers Ranking Parameters Based On Primitve, Citation Intensity And Publication Age

by

Qurat-ul-Ain

A thesis submitted in partial fulfillment for the degree of Master of Science

in the

Faculty of Computing
Department of Computer Science

2019

I dedicate my dissertation work to my parents, supervisor, and all other teachers. A special feeling of gratitude is for my father, the most unswerving man,I ever know in this world

CERTIFICATE OF APPROVAL

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1. **Ain, Q. U.**,Riaz, H., & Afzal, M. T. (2019). "Evaluation of h-index and its citation intensity based variants in the field of mathematics," *Scientometrics*, 119(1), 187-211.

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Acknowledgements

In the name of Allah, the Most Gracious and the Most Merciful Alhamdulillah, all praises to Creator and Sustainer of the universe for the strengths and His blessing in completing this thesis. This study is nothing, but an effort to understand and articulate the principles of one of the several hundred thousand phenomena, with a tool, the brain, a precious gift from Almighty.

I would like to express my sincerest appreciation to my enthusiastic supervisor, **Dr. Muhammad Tanvir Afzal** for his supervision, assistance, and immense knowledge. I am sincerely thankful to him for his constant support, motivation, and patience. His invaluable help of constructive comments and suggestions throughout the thesis work have contributed to the success of this research. It has been an amazing experience and I thank him wholeheartedly, not only for his tremendous support, but also for introducing me to the world of research.

My deepest gratitude goes to my beloved parents and siblings for tolerating my mood swings and being patient with me. A special thanks to my father for believing in me, for giving me the determination to overcome many trying moments to pursue my dreams. Heartily thanks to my mother for her love and moral support, coffee, and fries. A sincere thanks to my sisters and brother for their support, kindness and moral support during my study. Thank you my dear friend Nazia for helping me out in my darkest days and not letting me give up. Last but not the least and without hesitation, I would like to thank coffee, Goodreads, Akcent, and Pinterest, for helping me survive all the stress

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Abstract

Evaluating and determining the importance and findings of published research is very important for the growth of knowledge and research. A wide variety of parameters have been proposed by scientific community for the purpose of assessing the influence and contribution of researchers. Some of them are: authors number of publications, h-index, citation count, and many hybrid approaches. It is evident from the state-of-the-art literature that there is no gold standard or benchmark that is accepted as a standard to find the most suitable parameter for authors ranking and finding the authors with most impact in a particular field. Moreover, the research done on such parameters so far has featured very small datasets and often hypothetical scenarios. The small size of the dataset proves to be a hindrance in comparing and analyzing the parameters, and learning the importance of difference indices over others. Therefore, it is important to conduct a comparative study on a comprehensive dataset. This research helps with analysis of the primitive, citation intensity, and publication age based ranking parameters for authors ranking by applying them on the extensive dataset from the field of mathematics.It contains 62033 total publications and 57533 authors in total.

As previously stated, no standard benchmark exists that can be seen as the most effective way of ranking authors. Many rankings are based on only one ranking parameter and this is a cause for concern. Furthermore, the ranking parameters have been applied and evaluated on many different datasets. It is indeed a tough endeavor to find the effectiveness of indices individually. Hence, there is a pressing need to evaluate and comparatively study all ranking parameters while using an extensive dataset.

In order to confirm the validity of these parameters, first of all, the correlation among primitive, publication age, and citation intensity based ranking parameters is gauged. Afterward, all the ranked lists are searched thoroughly for determining which author ranking parameter has contributed the most in bringing the awardees in top list? Find out the most helpful parameter in determining the international award winners from 100, 500, 1000 best authors? We have also determined that

the performance of the primitive parameters, citation intensity and publication age based parameters differ between the different awarding society's? Lastly we have determined the ranking of the parameters (primitive, citation intensity, and publication age) for classification?

To answer the previously mentioned questions, the data considered as a gold standard is of four international mathematics award societies. The dataset contains 68 award winners from following award societies AMS, NASL, IMU and LMS.The present research will first analyze the parameters and then, based on those findings, determine the most accomplished authors in the field of Mathematics. During analysis of parameters it was discovered that, citation intensity and primitive based parameters have strong correlation while publication age and primitive based parameters have weak correlation. The rank lists are used to determine the award winners. 31.2% award winners were brought in to the top 10% of the rank list by 'Authors' Total Publication' parameter. In a nutshell, no index was able to bring 50% awardees to top ranking. The highest number of awardees from one society was 29 from AMS.This research is significant for both the researchers and decision makers.

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Abbreviations

AMS	American Mathematics Society
FPR	False Positive Rate
H-Index	Hirsch Index
IMU	International Mathematical Union
k-NN	K-nearest Neighbors
LMS	London Mathematics Society
MSC	Mathematics Subject Classification
NASL	Norwegian Academy of Science and Letters
NB	Naive Bayes
SVM	Support Vector Machine
TPR	True Positive Rate
WEKA	Waikato Environment for Knowledge Analysis

Chapter 1

Introduction

“ The heart and soul of good writing is research; you should write not what you know but what you can find out about ”. (Robert J. Sawyer)

1.1 Background

Measuring the quality and importance of scientific work of an individual has been found to be a very tedious task. On the face it, it does seem simple and easy but it involves complexity as it is not easy to fully describe a quality metric.

Dorta-Gonzalez et al. highlight the importance of such ranking by stating that it makes it more practical and easy to pick up the masterminds from any field. Moreover, a ranking system for scientists can help in deciding who well deserves a project, some funding or tenure. It can also help in determining the quality of academic output. A fair ranking system that determines the educational ability of the authors would make it easy for the conference organizers to decide on which author would be giving a keynote address. It would also help students tremendously as they would have a sound data clearly mentioning the achievements and abilities of their potential supervisors. In the light of that data, they would be able to make well thought-out and calculated decision regarding which professor should become supervisor for their research. The current criteria of measuring the researchers work greatly depends on the merits and standards created by the concerned scientist of the scientific community [1].

The ranking system will make the process of awarding scholarships and promotions fair and just. Moreover, it will also categorize scientific work based on impact and degree of innovation [1]. Metrics with several parameters have been proposed in order to acknowledge the contributions of authors in the scientific community. The paper describes different parameters that can be used to assess the significance of scientific work in any field. Scientists have been designing techniques to evaluate the educational ability of the authors based on their contribution to science. Each technique uses a unique approach to rank the authors by their potential and abilities [2]. Such techniques make use of both qualitative and quantitative methods. The published papers or the articles that cite those published papers have been used as the standards in some approaches in the past [3, 4].Moving on, the focus shifted towards measuring the impact of the researchers research work. To calculate the impact, parameters were introduced which not only quantified the production of researchers but also calculated the impact of the research publications.

To resolve the loopholes in the current ranking system, Jorge E. Hirsch came up with a leading metric, H-index [5]. The h index measures the current productivity and also the future impact of particular research work. The h-index is a quantitative measure, however it must be mentioned that H-index has eliminated many issues faced due to the total citation count. Hirschs index (h-index) is designed to gauge the standard and sustainability of research work. The h-index is an important measure for evaluating the performance of reserachers. The h-index is used internationally and the major reason behind such widespread use is its handiness that makes computing easy [6, 7]. Hirsh made improvements in the H-index till it became good enough to be accepted by the masses as the standard to measure the competence of the researchers in the scientific community. His work received attention of a lot of people and is now the most frequently used standard to rank scientific work. The h-index obtains the number of citations received by a paper and also determines the most commonly quoted research papers.

Originally it was designed to determine the quality of research work published by theoretical physicists. Hirsh states that the H-index can accurately predict whether the author has received a notable award like the National Academy Membership or a Nobel Prize. He calculated the h-index for 10 famous well-cited biomedical scientists and concluded that the authors who are cited the most have a higher h-index. Gianol i& Molina-Montenegro [8] identified that h-index is delicate to be self-cited for values above 8. But h-index is not affected in case of higher values. The h-index does not take into consideration the period of career of a scientist. Moreover, it does not make up for some areas where the process of publication is very slow (e.g. mathematics) or where the initiation of new research work is slow (e.g. engineering).

The h-index has some limitations [9]; it doesnt include the citations of top publications which means that two authors having different citations would have the same h-index. As quoted by Albert Einstein: *Not everything that counts is countable, and not everything that's countable counts.*

The reason behind this lacking is that h-index never copes with high-level values of citations and publications. The h-index depicts and treats citation and publication as two different dimensions. It represents that two opposite dimensional values can not be addressed without an element of conversion variable which balances out the effect of those opposite dimensional values. The author stresses that the delineation of h-index fails to explain the conversion value. Moreover, it is stated that the h-index does not accommodate the community factor which happens to be a very important factor when it comes to identification of best-ranked authors from any field or the potential experts.

In order to eradicate the specifications put forward by h-index a list of variants and different extensions have to be seen which include citation intensity based variants i.e." g-index (Egghe, 2006b), a-index (Jin 2006), r-index (Jin et al., 2007), q2-index (Cabrerizo et al. 2010), m-index (Bornmann et al. 2008), and hg-index (Alonso et al. 2010) [2, 6, 8, 10, 11] etc., Age of publication, which is based on parameters like AR-index (Jin et al, 2007), and m-quotient (Hirsch, 2005)" etc.

Raheel e al. expressed that there is no specific standard to rank the authors; a certain index forms the basis of most rankings [12]. Conventionally, when a new technique is put forth, it is developed by making many of small data sets [13] or on an imaginary scenario or on based on various data sets [14]. Moreover, these techniques are based and assessed on several types of datasets, which makes it arduous to capture the part played by each technique and the superiority of some over the others.

To distinguish which technique would give good results when it comes to ranking the researchers, a detailed assessment of all of these techniques should be done. Therefore, it is of crucial importance to assess and measure the ranking parameters on a comprehensive and extensive data set. To date, there is no benchmark present to identify the ultimate standard for ranking the authors. Most of the ranking in practice make use of single indices which raised a great concern. The reservations regarding the current methods encourage the scientific communities to develop new ways. This quest of finding new ways resulted in research on evaluation indices and subsequently a rapid increase in their limitations, pros and cons [12].

In order to know the parameter for ranking authors that provides the best results, these parameters should be evaluated in detail using datasets from one domain. This calls for the high need to evaluate the roles performed by primitive parameters "h-index, publication count, citation count", citation intensity based parameters including "g-index, a-index, r-index, q2-index, m-index, and hg-index" and publication age based parameters including Ar-index, and m-quotient. This research involves interrogation of roles that these parameters perform. The roles performed by these parameters are based on a comprehensive dataset belonging to mathematics domain. The primary objective of this research is to identify and extricate the indices that provide the best performance. The awards given by the mathematics awarding societies are considered as the gold standard for the sake of evaluation.

Some previous studies have also considered award winners of scientific societies as benchmark to evaluate researchers ranking parameters [12, 15, 16]. We have adopted similar methodology and have considered 24 prestigious awards of four

Mathematics prestigious awarding societies which are AMS (American Mathematical Society), IMU (International Mathematical Union), LMS (London Mathematical Society), Norwegian Academy of Science and Letters, to evaluate, citation intensity and publication age based parameters and find which of these have high correlated with primitive parameter. It is noteworthy that in this research we are not forecasting the awards however we are evaluating the performance of the primitive parameters, citation intensity and publication age based parameters in the field of mathematics. This study involves the evaluation of these parameters to identify the most influential authors in the said field. To meet this objective, we started by calculating the correlation among primitive, citation intensity and publication age based parameters. Moreover, we observed whether there are any publication age and citation intensity based parameters that have a weak correlation with the primitive parameters? Then we determined the level of correlation that exists among these parameters.

1.2 Problem Statement

Awarding societies and institutes of the scientific world are finding best authors based on ranking parameters. However, there is no gold standard available to determine the finest parameter to find the most influential author of a specific domain. Furthermore, it has been observed that such indices are observed on a limited dataset and ingenious scenarios. There is no proper study that evaluates the parameters on a comprehensive dataset. To distinguish which technique would give good results when it comes to ranking the researchers, a detailed assessment of all of these techniques should be done. Therefore, it is of crucial importance to assess and measure the ranking parameters on a comprehensive and extensive data set. To date, there is no benchmark present to identify the ultimate standard for ranking the authors. The small dataset is not sufficient to accurately analyze the nature of the ranking parameters and it is very difficult to determine and influence and significance of every parameter over the others.

1.3 Research Questions

1.3.1 Research Question 1

Find the correlation between the ranked lists of researchers acquired from the primitive parameters with citation intensity based, and publication age based parameters?

1.3.2 Research Question 2

Are all the esteemed awards winner, ranked higher from primitive parameters, citation intensity based and publication age based parameters and which author ranking parameter has contributed the most in bringing the awardees in top list?

1.3.3 Research Question 3

Find the correlation between the ranked lists of researchers acquired from the primitive parameters with citation intensity and publication age based parameters?Which ranking parameter of above mentioned parameters helps the most in elevating the national and international award winners to be ranked among the best 100, 500, 1000 authors?

1.3.4 Research Question 4

Is the performance of the above mentioned raking parameters differ between the different awarding society's?

1.3.5 Research Question 5

What is the researchers ranking of the parameters for classification?

1.4 Purpose

The purpose of this research is to evaluate the primitive, citation intensity based and publications age based parameters contribution in researchers ranking process. To assess these parameters, national and international prestigious awards are used as the standards. Some previous studies have also considered award winners of scientific societies as benchmark to evaluate researchers' assessment parameters [12, 15, 16]. We have adopted similar methodology and have considered 24 prestigious awards of four mathematics award societies to evaluate the parameters.

1.5 Scope

The scope of this research is the evaluation of primitive, publication age and citation intensity based parameters to rank the authors in Mathematics domain. The primitive, citation intensity and publication age based parameters include publication count, citation count, h-index, g-index, q2-index, a-index, r-index, hg-index, m-quotient, ar-index and m-index. The benchmark dataset contains researchers of four prestigious international awards societies of mathematics i.e. AMS, LMS, IMU, and NASL.

We will exploit this dataset to acquire the correlation among the above mentioned parameters in the mathematics domain. We will evaluate either the performance of the these parameters(primitive parameters "h-index, publication count, citation count", citation intensity based parameters including "g-index, a-index, r-index, q2-index, m-index, and hg-index" and publication age based parameters including Ar-index, and m-quotient).

This research involves interrogation of roles that these parameters perform differs between the different awarding society's or not and which parameter helps the most in elevating the national and international award winners to be ranked in the top 10

1.6 Application of Proposed Approach

This research will help various groups of people in the under mentioned ways:

1.6.1 Decision Makers of Scientific Societies

The comprehensive results of our research will enable decision makers to make informed decisions regarding authors that have little or no citations like, whom to give promotions, whom to offer memberships and whom to present prestigious awards.

1.6.2 Authors Who wish to be Known as Experts

An aspiring researcher can make his mark in the scientific world by his network on co-authors. His connections can lead him to greater career options.

1.6.3 Expert Finding Systems

The proposed parameters can be used by expert finding systems to rank authors. Hence the results of this research can aide expert finding systems.

1.7 Limitations

We have taken the comprehensive dataset of mathematics domain. We have evaluated the performance of primitive, publication age and citation intensity based parameters for the ranking of researchers belonging to the mathematics domain. However, it does not cover all the researchers of mathematics domain.

Chapter 2

Literature Review

2.1 Introduction

To appreciate the efforts of researchers in the scientific society, a various number of metrics or parameters are propounded for instance the total publication count of the researcher. On account of all such parameters, they are positioned by the scientific journals or scientific communities to mark which researchers are important. There are many ways through which researchers can be positioned for example the best researcher can be selected as the editor or the reviewer of the research study [17]. A standardized ranking system plays a very important role in making judgments about certain crucial decisions in the scientific community. It would help to determine whether a particular scientist should be given an award or a higher rank in the scientific world. It also plays its undeniable role in determining which individuals should be allocated the service period. Similarly, it helps with the allocation of contracts to the professionals and also helps the researchers in deciding which contract opportunities should be availed [17].

To rank, the researchers have appeared as a crucial issue in the whole scientific society. One another reason of positioning the authors in ranks is to find out the scientific impact of the researcher and take him to offer the post-doctoral posts, duration and small posts faculty [18]. Different institutes can invite the authors or researchers that have been ranked the best, as their chief guests or orators. Various techniques are used to rank the researchers, or even journals or universities. For example, publication count, citation count, co-author, hybrid approaches, h-index, etc. have been used to rank researchers Note that it is important to rank the authors in a way that is fair and just. These parameters cannot be universally applied to individuals. Also, it is found to be very challenging to develop a comparison between two types of researchers; one who is regularly contributing to the scientific world be publishing dozens of research papers every year and the one who does not contribute regularly but focuses of creating a few big shots [19]. Smolinsky and Lercher (2012) analyzed citation counts of various renowned scholars in the field of mathematics and its subcategories. They concluded that the difference in citation counts is mainly because of the way publications are published or the way they are internally cited. They elaborated that certain subcategories of mathematics can attain better citation count simply because of their association with the fields that are highly cited [20]. Behrens and Luksch found that citation count only picks out a few of subfields in the field of mathematics. They stated that it is mostly ignorant of a lot of subfields [21].

To overcome the shortcomings of citation count and publication count, researchers proposed a parameter called the h-index. It was proposed by Jorge Hirsh in 2005. Even though the h-index is intrinsically restricted, it is popular in the scientific community because of its simple and easy application [22, 23]. The conventional system followed by the h-index has various inefficiencies. To counter these inefficiencies, the authors proposed two further extensions of the h-index. Researchers have proposed three versions of the h-index; the first one is referred to as the standardized h-index while the other two are named as the contemporary h-index and the trend h-index [24].

In another study, it was stated by Wu et al. that an average value of h-index quadruples the total of w-index. We introduced a new index, i.e. w-index. It was proposed as a meaningful way to measure or determine the influence of an authors' research, mainly the impressive ones. It is concluded that the papers assessed by using w-index had prominent differences when compared with h-index since w-index pays more attention to the well-cited works. W-index can be used to gauge the researchers, research cells, organizations, and scientists, etc [25]. Yan et al. took into account 29 various indicators including 26 variants of h-index and measured the direct relation among the h and wu indices. They discovered that with some exclusion most indices that share a direct relation with h-index are not much connected to Wu-index. Likewise, parameters which share a direct relation with Wu-index are not much connected to h-index. It is also visible that the indices which have a direct connection do not show much development over h and wu indices and should be left or be combined with these indices [26].

Jin et al. propounded a pattern to exploit a blend of h and r-index or a blend of the h and ar-index. All these pairs were applied to discover an indicator for the researcher's assessment. Usually, one index is termed as qualitative and other as quantitative when they are joined in a pair. They've found that the pair h-index, ar-index serves a better indicator for research assessment that the others [27].

Mazloumian et al. introduced an index based on a specific network. This index assesses and measures the scientific productivity that is then used to conduct a thorough worldwide dissection of erudite knowledge. It also plays a role in pervasion based on geography [28].

Fukuzawa et al. analyzed the distribution of research publications and citations that have been patented. The study also included an estimation of the relationship that existed between them. The sample consisted of over 4000 published works and the correspondents of this sample were regarded as the top authors in Japan. The study found that there is a U-shaped connection between them [29]. Ayaz et al. measured the h-index and its other variants like complete-h and g-index etc. this measurement was based on a set of data gathered using mathematical techniques. To draw a comparison between the indices, the national and international award winners were standardized and used as a merit in the field of mathematics. This work found that the complete-h not only completes the h-index but also adds the community factor to it (the effect of the community). The performance of complete-h was found to be better than h-index and g-index when adding the awardees in the top ranking list [15].

2.2 Expert Finding System

The assessment of the research work of a researcher or the measurement of the productivity of a journal or even a conference has always been a subject of great interest, because of the advantages gained by approaching an unprejudiced and objective criterion. The research field that uses quantitative and qualitative approaches to rank institutions and journals is called Scientometrics. Paper level metrics, author level metrics, and Journal level metric are the 3 metrics used in scientometrics. Many techniques have been put forward by researchers to rank authors, papers, journals, and institutes. Scientometrics was used by some Chinese Researchers to rank global universities [30].

The purpose of that study was to pinpoint why there is a gap between worldwide universities and Chinese universities. The study attempted to use research activity as the parameter for ranking university. Based on the researcher's work impact the different methods can be espoused for ranking the researchers. Every method has a gold standard for the author's ranking. According to Sidiropolous et al. there exist three most used techniques when it comes to the assessment or evaluation of scientific work. The first way states that this can be done by asking some professionals to do the ranking and second way depends on the citation count which includes going through the related articles of the given item. An amalgamation of both ways can also be used [31].

The first way makes use of an improvised method, which functions by collecting the opinions of numerous specialists of a specific field. This kind of approach is extremely intriguing since it ranks, following the opinions of not just the readers but also the writers, which can never be truly described via the examination of different patterns of citation. This method doesn't work on pre-planning. Rather, it has been regarded as an impromptu method. Moreover, this technique gives the freedom to experts to rank the researchers whichever way they like. This method is intriguing considering that it is not based on citation count and that it takes into account the opinion of the authors that they form by examining all the works. However, because this method is manual, it is prone to objectivity.

To assess scientific work, a function of an objective that measures some score has to be defined. The quality metric is used to determine the impact and efficiency of the researcher's work, therefore we cannot easily define it. Sidiropoulos proposed a different method for examining the research works. The method involves creating a tool that would compute the scores gained for the objects being examined while taking into consideration, the graphic representation defined by the total number of citations. Ranking a publication according to its quality and other metrics is not an easy task. The common methods mostly in practice make use of basic arithmetic functions to rank the publications like the number of citations or the total number of publications authored. Sidiropoulos did a comprehensive study on such methods in 2005 and the following year (2006), he came up with the idea of combining the two techniques. He suggested that the rankings can be obtained by taking out the average of both approaches. No single method can perfectly rank publications but the one involving citation count is the most popular. This is because the citation count method is not manual and is free of human errors. Moreover, this automated and mechanical method makes use of digital libraries by observing the given information related to citation count. The third approach regards national and international prestigious awards as the standard benchmark to assess the researchers [31].

The existing state of the art is based on some mathematical elements such as the number of papers published, number of papers written by a researcher, number of papers written per year, number of citations and the number of citations per paper. It never differentiates between researchers with a low quality of maximum impact papers and researchers with a high quality of minimal impact papers. It high focuses on providential maximum impact papers when a scientist has a minimal impact career and is overly dependent on the area of research and the duration of the researcher's total career. The measuring system which is dependent on the number of papers does not measure its meaningfulness or the impact. A negligible number of megahits affect them highly. Although the measuring system based on several citations might not have an enormous impact.

In 2005, Hirsh stated that the intellectual ability and academic influence of the authors can't be accurately determined simply by counting bibliometric indices. He then proposed a new ranking measure called the h-index. He explained that the h-index can proficiently rank the authors as it combines the citation count and the publication count [5]. All the indices mentioned in the above mentioned paragraphs are only applied to small data sets that are not too comprehensive. H-index was used by a researcher to gauge the author performance based on factors like citation count and publication [32]. It was also identified that h-index can also be used to calculate the impact factor of a journal [32].Ten years ago, author ranking was done on the bases on bibliometric indices. In the scientific community, an author's ranking is determined based on publication count, h-index and g-index. While many parameters have been proposed they pose a problem for new authors who have published but haven't yet received any citations. Such fresh authors require recognition by scientific societies so they can get better jobs, or the chance to be the editor or supervisor of a reputed journal. Reputed science journals are looking for the top authors on the bases of the person's contribution to research [33].

To date, various variants and extensions of h-index have been introduced. In research on h-index Schreiber et al. took into account the 17 variants of h-index and also some bibliometric standards determined that indices can be classified into two categories i.e. quantitative and qualitative. Therefore, they determined that these two assessments should be applied for the calculation instead of h-index and its variants. He has also performed a meta-analysis of the h-index along with its variants. In this meta-analysis, a heavy and a direct relation between h-index and its variants were depicted. It also shows that these parameters add very little to h-index [34]. The correlation of the h-index and h (2)-index was studied in 2006 by Kosmulski. The experiment to study the relationship was carried on data of 19 chemistry professors from a university in Poland [14]. The experiment gave the conclusion that h-index and h (2)-indexparameters have a strong correlation, hence the results calculated using both the parameters is identical. The h-index was compared with various other parameters in a study done by Van Raan. To study the correlation, Van Raan used the data from the evaluation done on 147 Chemistry research groups of the Netherlands. The primary focus was not on individuals but research groups. Furthermore, the citation count was limited to a 3-year time frame as opposed to full life citation count [23]. Examining researchers of a particular field proves to be very important in most cases of consolation in academia.

We have discussed a lot of parameters which are used to determine the efficiency of publications or to find the most persuasive researchers. Following are the derivations we concluded. Researchers have been ranked by applying their bibliometric indices, almost ten years ago. The effect of the researcher in the scientific society is calculated by applying h-index, g-index and publication count. Researchers have propounded several parameters who have added their efforts towards scientific society. This has become a concern for those authors who have published their works lately with no citations. The researchers who are at the beginning point of their careers in academic fields should be given due recognition by scientific communities or the professionals who rank. Moreover, the parameters that have been discoursed above are mostly assessed for imaginary cases. All the above-mentioned parameters are applied to data sets that are not too inclusive. Also, no parameters or standards exist when it comes to the assessment of these parameters. A standard system is required to serve the assessment of these parameters.

2.3 Critical Analysis

One parameter that is widely recognized for ranking of researchers includes the total number of research papers published the impact of these papers on the scientific community that is identified by the Journal impact factor. The number of times the research papers are cited is also an important factor that impacts ranking [5].

These parameters have faced a lot of criticism due to their incapability to bring about proficient ranking. However, alongside drawbacks, all parameters have their specifications. The number of publications, for example, is a measure of production. It doesn't take into account the importance or the scientific influence of the publication but it only depicts the quantity of research work. Thus, any researcher who has authored a lot of publications can be regarded as a high-performance researcher even if the quality of his research work is not up to the mark. Only the publication count is not a sufficient parameter to rank researchers because many researchers publish their papers in low quality journals and conferences [3].

Another feasible parameter is the total citation count [4]. The total number of citations, on the other hand, can be effortlessly oscillated by only 2 or 3 exceedingly popular publications or review papers. It's a simple and a straightaway given metric, however, this metric needs to be observed with huge care. This metric lacks in differentiating between the researchers producing a low level of productivity of research papers with high impact rate and the ones who possess the quality of high-level productivity with low impact rate. It highlights the papers with a high impact rate when its author has a low impact career, taking into observation the scientist's area of research and the time of his career. Moreover, sometimes authors cite their own papers and sometimes other researchers cite the paper to give criticism instead of acknowledgment. The number of citation count has received a lot of criticism due to its loopholes and it happens to be a controversial subject. Moreover, citation counts and citation rates differ tremendously depending on the type of field.

Another most widely used parameter for authors ranking is h-index. The h-index can portray the influence and productivity of a research publication just through one value or figure. It considers both the number of publications and the total number of citations to determine the importance of a researcher. The h-index has a lot of advantages but it is still not a perfect ranking technique. One of the disadvantages of h-index is that sometimes it tends to blend the number of citations and total publications [5]. The h-index can portray the influence and productivity of a research publication just through one value or figure. It considers both the number of publications and the total number of citations to determine the importance of a researcher. The h-index has a lot of advantages but it is still not a perfect ranking technique. One of the disadvantages of h-index is that sometimes it tends to blend the number of citations and total publications. If a publication gets nominated within the core publications of the h-index, the value of h-index is affected in case of an upsurge in citations of the said research work [6].

The h-index lacks in providing a better highlight of an author's impact on his area of research since it heavily relies on the results and academic aura. Hence, it is not the best option when it comes to being used as an instrument for drawing comparisons. Moreover, h-index strictly undervalues the overall impact of the researcher, especially if the author turns out to be the one who has one or more papers that are highly cited. The numbers of papers published by a researcher are never truly acknowledged by h-index since it focuses more on quantity than quality. Hence, it can be suggested that h-index is based on the quantity that an output brings. Another drawback of h-index is that it can't distinguish between two researchers having a similar h-index [18].

Hirsh assumed that this similarity can be differentiated by self-citing the publication. It is not easy to gather all the data required for calculation of h-index. At times, a complete list of total publications authored by the researchers is required to distinguish between two researchers sharing a common name. Another issue regarding the h-index is that it can't acknowledge new researchers as they don't have a lot of papers published and also have comparatively low citation rates. H-index allows scientists to depend on their previously earned awards and laurels through an increase in the number of citations. Thus, a scientist can have a good h-index even if he is not publishing any new works. H-index is not of use when comparing the average scientists; it can only compare the best scientists. H-index has its shortcomings and to get rid of its flaws, many formulas have been proposed so that the scientific productivity of the authors can be assessed completely [2].

Aoun et al. conducted a study on indices that are used to determine the scientific productivity of the authors. The author found that the h-index is one of the parameters that are known for their rigidity against the effects of self-citation. Moreover, an increase in h-index shows that it has been affected by the period of an individual's educational life. That is why h-index puts the junior researchers at a risk and thus, it is not suitable for judging the authors at different levels in their profession [19].

2.4 International Awards

Due to the fact that a standard benchmark dataset doesn't exist in this area of research, we have used scientific society's awards as a benchmark for our research. In every field, awards are presented to the top researchers and Mathematics is no exception. We have considered data of 24 awards including ones organized by American Mathematical Society (AMS), International Mathematical Union (IMU), Norwegian Academy of Science and Letters (NASL), and London Mathematical Society (LMS). The list of winners of the awards was used as a benchmark.

There are total 104 award winner. Out of 104 awardees, 2 award winners received more than one award. The removal of this duplication leaves 102 awardees. The 68 awardees were found in the dataset. The final data set can be seen in Table 3.1. As thousands of citations were covered in the collected data we can say that the data is comprehensive but we still cannot make the statement that every publication of a particular author is included. But the data was used to calculate all the parameters so they can be easily compared [35].

2.5 Awarding Societies and their Significance

In every field of knowledge, an awarding society plays a key role. An awarding society is with the mission of acknowledging the contributions of people. There are many awarding societies in the world of Mathematics, some of which are as follows:

2.5.1 American Mathematics Society

The American Mathematics Society was established for mathematical research and scholarships. Its meetings, publications, and various other endeavors greatly benefit the nation and the whole mathematical world. With the help of some other institutes, American Mathematics Society organizes the biggest annual mathematics meetings. Its publications include journals, books, reviews and database of reviews. Following is the list of awards associated with the American Mathematics Society.

2.5.2 The International Mathematics Union

The International Mathematics Union is a global scientific organization which aims to promote worldwide collaboration in mathematics. It also aims to support conferences and meetings and works in all the subfields of mathematics. Following is the list of awards associated with the International Mathematics Union society.

2.5.3 London Mathematics Society

The London Mathematics Society is based in the UK and its some is to publish books and journals. It also gives grants to researchers of mathematics and holds lectures and meetings. Following is the London Mathematics Society awards and their winners:

2.5.4 The Norwegian Academy of Science and Letters

The Norwegian Academy of Science and Letters is not focused on any particular field of knowledge; instead, it corresponds with various areas of knowledge.It has a comparatively lesser number of awards as compared to other awarding societies. Following is the list of awards associated with the the Norwegian Academy of Science and Letters society

Table 2.1: Mathematics Prestigious Award Socities

AMS	**39**
Bocher Memorial Prize	1
Cole Prize in Algebra	2
Cole Prize in Number Theory	1
Dellbert Ray Fulkerson Prize	7
Joseph L. Doob Prize	1
Leroy P. Steele Prize for Lifetime Achievement	4
Leroy P. Steele Prize for Mathematical exposition	8
Leroy P. Steele Prize for Seminal Contribution to Research	5
Leroy P. Steele Prize for Seminal Contribution to Research	8
Osqald Veblen Prize in Geometry	2
IMU	**8**
Chern Medal Prize	1
Fields Medal	4
Guass Prize	1
Leelavati Prize	1
Rolf Nevanlinna Prize	1
LMS	**37**
Berwick Prize	3
De Morgan	2
Frohlich Prize	2
Naylor Prize and Lectureship in Applied Mathematics	1
Polya Prize	1
Senior Berwick Prize	3
Senior Whitehead Prize	2
Whitehead Prize	23
NASL	**20**
Abel Prize	4
The Kavli Prize	16

Chapter 3

Research Methodology

3.1 Introduction

The scientific community continues to propose different approaches to rank researchers' in different domains. It has been identified from the observations made from chapter 2 that researchers ranking usually done by using citations, h-index, and the total number of published papers, or any combination of these parameters. There is no comprehensive study found that can be used to assess the role of rankings generated by these parameters. To conduct, the evaluation, prestigious national and international awards that are won in the field of mathematics are considered as a gold standard.This section covers the methodology in detail while the diagram of suggested elucidation methodology is given in figure 3.1.

3.2 Domain Selection

To practice the technique, compressive data from a specific academic department is required. We chose the field of mathematics to test the primitive, publication age, and citations intensity based parameters.Data set has been received by the former research. The field of study was selected after careful consideration of several factors. Firstly, it was ascertained that the selected domain has the diversity

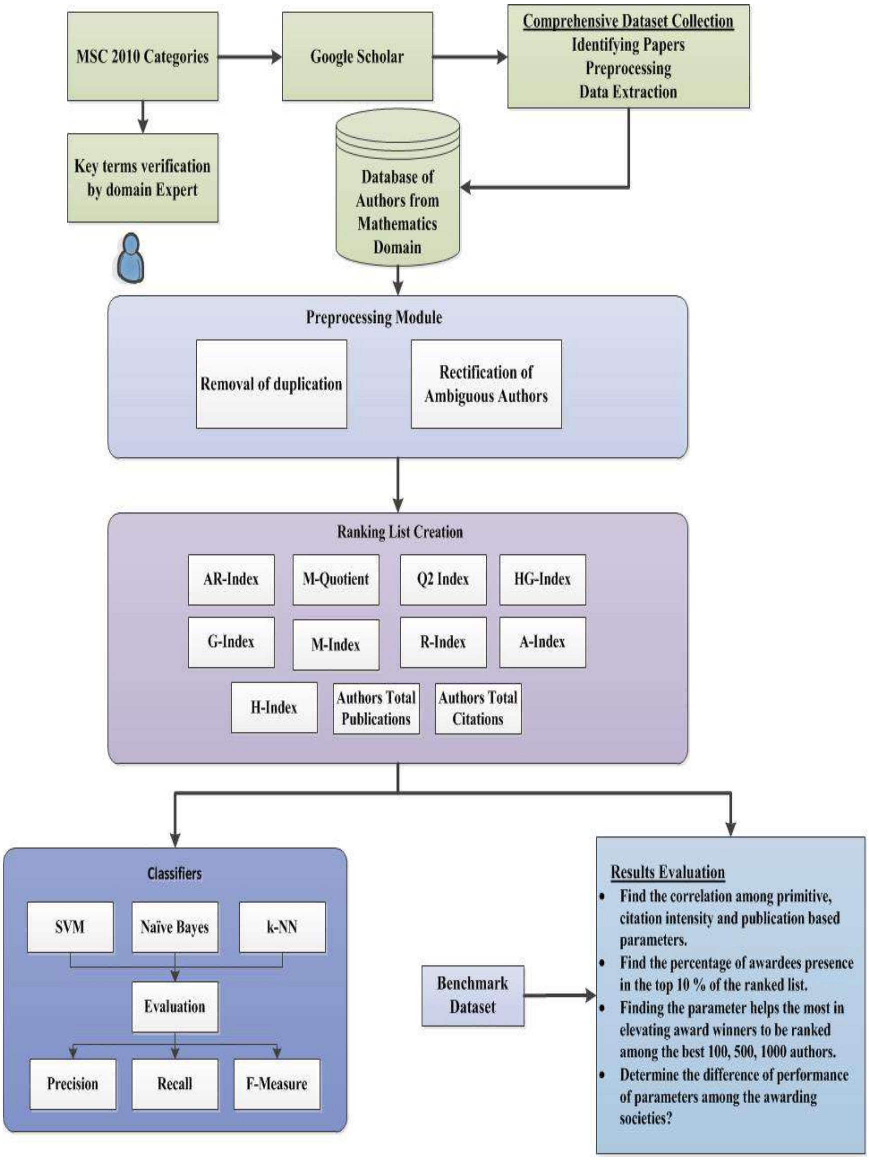

FIGURE 3.1: Block Diagram of Methodology.

required to test the above mentioned parameters. Another important reason behind this selection is that mathematics happens to be well-linked to all the other branches of science i.e. computer science, physics or chemistry. Thus, the chosen domain is diverse and ranking scientists according to this would be an immense execution. It is important to test these indices in other areas too because this would contribute towards the promotion of academic growth and development. It would also help figure out the practicality and competence of all these parameters (”primitive parameters: author’s total publications, authors citation count, and h-index; citation intensity based parameters: q2-index, r-index, a-index, g-index, hg-index, and m-index; and publication age based parameters: m-quotient, and ar-index") which would further help in ranking the researchers.

3.3 Taxonomy Building

Mathematics is a versatile domain that is linked to all other fields of study. To retrieve the dataset, the crawler was designed that makes Google Scholar crawl to retrieve the dataset for publication to be applied in mathematics. The data retrieval was done using MSC (Mathematics Subject Classification) as the basis and some keywords were introduced to be entered in the crawler [15].

Those key terms were to serve as an input for the crawler. Mathematics Subject Classification was invented by editorial departments from two well-known foundations i.e. the database of bibliographic records. The current version of MSC i.e. MSC2010 is comprised of 64 sections that have been categorized into 2 digits and further furnished into more than 5000 three-five digit divisions. Many of these divisions use a certain list of words that yield unnecessary and unrelated search results when searched in Google Scholar. MSC 2010 is the most recent version of Mathematics Subject Classification. The top best categories that make up this set of classification are 64 in number that is further categorized into two distinct sets; 19 related to applied mathematics and 45 related to pure mathematics. This resulted in the creation of a taxonomy that is comprised of 45 top levels and 239 sub levels.

The categories use general keywords and hence cause Google Scholar to produce irrelevant results. One such situation has been illustrated in Fig. 3.2. The category provided in the example query was 'General Logic' which has the code 03Bxx in MSC 2010 but some output results are given by Google Scholar are belonging to Computer Science; this is clearly shown in the Fig. 3.2. Owning to this problem, the help of domain experts was sought to gather focused and domain specific keywords. With aid from experts, a new list of categories is created. This list enables accurate data search from Google Scholar. The results that appear upon searching for a topic are usually related to the term that was searched. Or it can

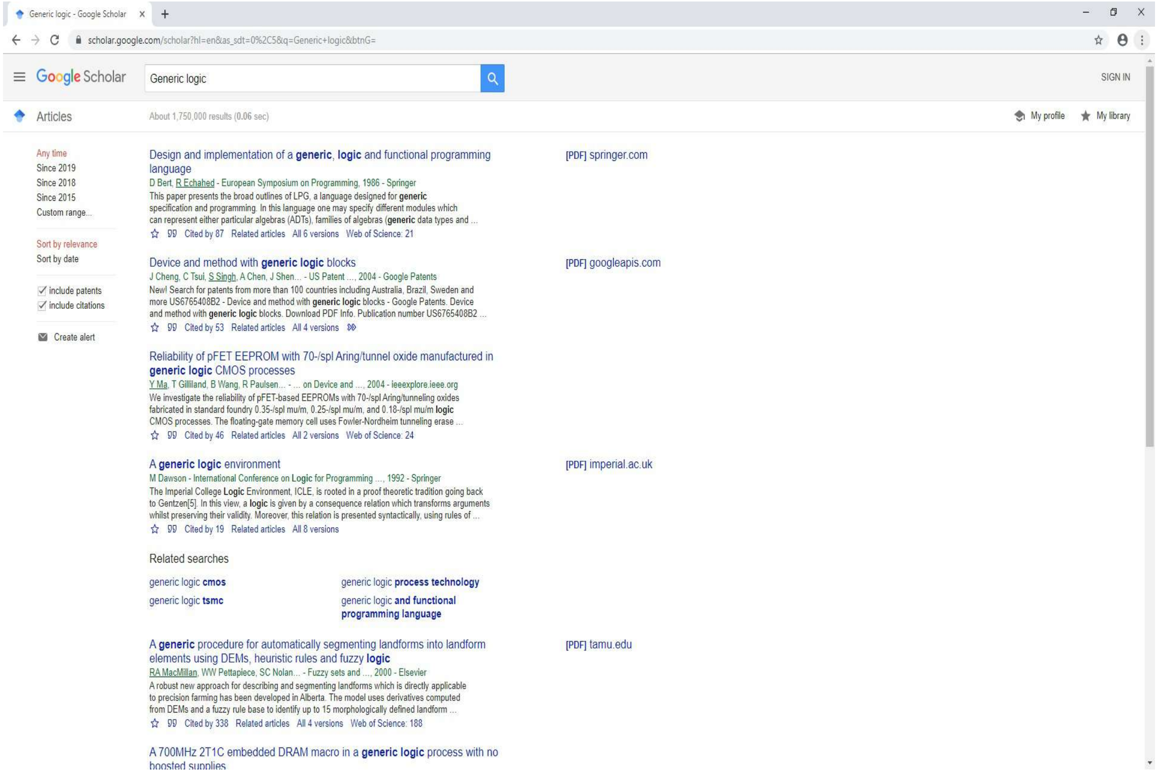

Figure 3.2: Irrelevant Results.

have a connection with the received number of citations. Hence, the papers that came on top as a result of the search were included in this study.

A total of 600 top results were selected. This was done because usually the top 600 results are most relevant and answers start to become vague and irrelevant after it crosses the top 600. All the necessary information about the publication including the name of the paper, names of authors, name of co-authors, publication year, the address, number of citations and the names of journals it appeared was included.

3.4 Search Engine

To collect the data of publications, citations, and authors against Mathematics Subject Classification categories, we have used the Google Scholar. While many other options were available, for example, Scopus and Web of Science, Google Scholar was preferred due to its massive library of publications in comparison to the others [36].

Another reasoning behind the choice was the fact that Google Scholar gives the public access to the resources while resources like Web of Science only provide limited access. Google Scholar does citation indexing and data entry related to all avenues of science and makes them easily accessible. Google Scholar has huge library of research papers in comparison to the others sources. Furthermore, according to the latest study, the growth of Google Scholar surpasses Web of Science by 13%. There is a 1.5% increase each month in the amount of citations on Google Scholar [**?**]. Citation noise i.e. double citations, non-scholar citation, etc, is lesser in Google Scholar compared to Web of Science and Scopus [37].

A statement by Google Scholar claims that new additions are made to the Google Scholar several times each week. This leads us to the conclusion that Google Scholar is regularly added to. According to a Harzing study, to update the existing records, and the addition of new records is done every 2-3 months in Google Scholar [36].

The comparison of Google Scholar with alternatives like Web of Science is a task that was undertaken by many researchers. Moed at al. concluded that Google Scholar was the best source to get a publication, citation, and metadata [37]. Walters, 2009, highlighted that Google Scholar is popular because of its precise and accurate results and this conclusion was made based on a comparative study with 11 other search engines. Google Scholar is reliable and unique because it is inclusive and diverse when it comes to Bibliometric and citation analysis [**?**]. Based on all this, we chose Google Scholar to gather our data.

In light of the above mentioned arguments, we can conclude that Google Scholar is the most suitable source for data about publications, the authors of publications and citations. The method used by Google Scholar to filter records according to a query is explained by [38].

They stated that the relevancy of results decreases from top to bottom. The measure for relevancy is the number of times the query appears in the title of the paper. The most highly ranked and cited papers with the most relevancies are provided at the top. The crawler was fed the terms from classification to gather data of authors and publications.

3.5 Scraping Module

The data was collected via a dedicated crawler which extracted the metadata including, paper title, conference or journal where it was published, name of author, paper URL and paper citations of authors belonging to category from the Google Scholar database.
The mathematics subject collection process was as follows; firstly the chosen subcategories were input to the crawler, then the crawler found the papers that fall under that category from the Google Scholar database, and finally, it produces the records as output. For this purpose, a dedicated crawler was created; it collects the data of many publications, coauthors and citations of topics belonging to the mathematics subject classification category.

The reverse engineering of Google Scholar's algorithm of ranking by [38] shows that the highest ranked results are the most relevant to the input query. The term relevancy is defined by the number of times the query word occurs in the paper title. Each result is ranked based on 2 parameters; first is how relevant is it to the query and second is the total citations it has. Due to above mentioned reasons, this study uses the most cited and highly relevant research papers as provided by Google Scholar.

A subcategory from the updated list is fed as input and 600 records were crawl for each subcategory by Google Scholar. Only the top 600 results were considered because it was observed that beyond the 600th result, Google Scholar shows papers irrelevant to the query. All the records are saved to an SQL database. If the number of results for a particular query is less than 600 than that number is simply saved to the database.We gathered all the data related to a publication like the URL, authors, number of coauthors, title, year of publication, total citations, and conference or journal name.

3.6 Dataset Description

Google Scholar is used for the collection of data about the researchers' published and cited works against the classification system of MSC. The crawler plays its role by providing the list of classifications to Google Scholar. It collects the title name of the published research papers, the name of the researcher, and the conference or journal where it was published. It also takes into account the total number of citation count, the URL of the published research work and the date of the publication. To make sure that the data is authentic; all 64 domains were subjected to verification and review by the domain experts. The dataset of mathematics is constituted 57533 authors and found 57515 authors after the removal of ambiguities by former researchers. However, there remains the issue of duplication and ambiguous author names that has been rectified manually.

3.7 Pre-processing

On this dataset of mathematics, pre-processing has been done to filter the dataset in two dimensions. One dimension is to check whether or not the data belongs to the domain of mathematics. The other dimension focuses on the removal of the duplications and correction of vague last and initial names of the authors. The section summarizes the methodology in a way that ranking list from the h-indices is examined in order to find a presence in the awardees on the top who are given esteemed awards to honor their remarkable contributions in the world of science. Some basic steps were followed to ensure the authenticity of the data including:

- Eradication of search results having irrelevant titles. A total of 69,527 results were gathered out of which 169 were found to have irrelevant material which was not related to the publications in any way.
- After the elimination of said 169 results, 69,367 results were left. All these publication were examined and their places of publication were filtered and analyzed.

TABLE 3.1: Mathematics and Benchmark Dataset Information

Total publications	69,197
Total authors	57,533
Number of citations	8,821,251
Total award winners (Benchmark dataset)	104
Award winners after removing redundancy	102
The award winners found in the dataset	68

- An examination of the places of publication revealed that not all of them belonged to the mathematics journals. A total of 9368 publications never appeared in the mathematics journals. All the publications that were found to have no connection with mathematics were excluded. So, we were left with a total of 69,197 publications.

A final glimpse of the statistics is presented in Table 3.1. The gathered data was precise as a lot of citations had to be acquired but it cannot be said that all the works of every author were collected. All of the different indices used for ranking were compared and applied to the gathered data. Therefore, results can be computed for all parameters.

3.8 Data Cleaning

Various authors believe that data collected from Google Scholar has noise and must be cleaned [15, 39, 40]. The cleaning of data was done with two dimensions. The first dimension is to discussed whether the data is relevant to Mathematics or not? Author disambiguation is the focus of the second dimension. The following steps were taken in lieu of the first dimension:

- The records which had titles that contained invalid characters like *,&, \etc were removed. Out of the collection of 69,527 publications, 160 records fell under this category and were not valid publications. Removal of the 160 left 69,367 publications behind.

- All papers, either journal or conference, were verified. The verification was done by filtering publication records based on place of publication. The place of publication can also be used to find the domain of a research paper, as suggested by Dunaiski et al. [35] e.g. all papers from International Conference on Software Engineering are automatically categorized as Computer Science. Hence, any record which was not actually published in a Mathematics journal or conference was removed. A total of 9368 records had to be removed.

- Verification by paper title done by domain experts. The remaining 9368 papers were presented to experts who pointed out that 169 did not belong to the Mathematics field. This left a record on 69,197 publications.

For the second dimension, it is made sure that every author is disambiguated [41]. To remove ambiguity records were checked for any duplicate author names. To perform this check, a common second name is found. When more than 1 author has the same name, especially last name or when the same author name exists as different variations in the database, we need to ensure author disambiguation. After analysis of both first and last name, it was concluded that if both first and last name of more than 1 author match then author duplication is present. We also performed a manual check by visiting the authors' profiles on the homepage.

Author disambiguation was the second step of our process. Out of total 57,533 authors, same last name occurred in 29,263 records and had to be disambiguated. It was found that 7744 names were being shared in the 29,263 records. Some names were shared by 100s of authors while others were shared by as less as 2 authors at a time. Two cases occurred when checking for author disambiguity; one where the last and first names are identical and the other where first names were unique while last names were identical. The inspection of the 7744 records revealed that there is no such entry where the first and last name is same. To check for case two, homepages of authors were observed and it was revealed that out of 7744 records 4945 were such that they had different first names and identical last names were separate people. But the rest 2799 records were variations of the same author name.

3.9 Tools and Technologies Used

- Weka tool
- Machine Learning Classffers (SVM, Nave Bayes, k-NN)
- Python 3.8
- Microsoft Excel

3.10 Benchmark Dataset

Evaluation of parameters in this ranking procedure requires a comprehensive and extensive gold standard or benchmark dataset. Hence, in this study, the prestigious national and international awards are used as a benchmark or gold standard. Many people are given awards in exchange for their remarkable contributions in different fields. Similarly, major contributors and high achievers are given many esteemed awards and honors in the field of mathematics too.

This study focuses on the data of different award winners who were given the 24 most esteemed laurels. These laurels are usually provided by different mathematical societies working in various parts of the world. A total of 104 awardees were considered, out of which the unique awardees were found out to be 102. These awards were given by "International Mathematical Union (IMU), American Mathematical Society (AMS), London Mathematical Society (LMS), and Norwegian Academy of Science and Letters (NASL)". The details of the awarding societies and their award have been given in Appendix B.

3.11 Expert List Creation

This module is dedicated to the creation of the ranked expert lists. We have chosen primitive, citation intensity and publication age based parameters. Appendix A depicts the formulas of those parameters. Extraction of all indices is done by scripts. All data is saved to a relational database. The macros needed to find total citations, g-index, h-index, m-index, a-index, r-index, ar-index, hg-index, q2-index, m-quotient, and total publications are also saved in the database.When we were done calculating we ranked each author relative to each index. In the end, we are able to get 11 different standards in which we ranked the authors.

3.11.1 H-index

The h-index was proposed in 2005 by renowned researcher Jorge Hirsch [5]. It is an index used to evaluate the impact of publications and their authors. The number of citations is considered as the measure for total publications done by an author, in many of the scientific measures that are contained within the h-index.A measure of the contributions of a single author called h-index was presented by Jorge Hirsch in 2005. The number of publications equal to the number of citations. The h-index is being researched on from the different point of views. Michael has searched for compounds and topics in the area of physics. People who get post-doctoral scholarships have higher h-index than those who don't. Scientists have been hard at work in finding various applications of the h-index e.g. Michael found new areas of components and study. The authors that got selected for high-level research projects had h-index more than those who didn't [2].

H-index is the most innovative, and it is this quality that makes it remarkable. It can be used to search out the odds between old and new researchers. Moreover, it has also provided aide to new researchers in finding works already done in the field they are interested in. It can also calculate the impact factor of a researcher paper. The prime aspect of the h-index is that it can position researchers based on their impact. Moreover, it applies lesser limitations as compared to other indices and is hence broad. Although, one drawback of the h-index is that it does not credit papers that have fewer citations.

H-index is becoming the latest and most efficient way of indexing these days. It can also help separate new and old topics and is hence helpful to the researcher who wishes to view the current research on a particular topic. H-index measures both the paper quality and the impact of where it was published. One key advantage of h-index is that it takes into account both the paper quality and research impact and hence it makes the ranking of authors easy. "The problem is that Hirsch assumes equality between incommensurable quantities. An author's papers are listed in order of decreasing citations with paper i having C(i) citations. Hirsch's index is determined by the equality, h = C(h), which posits equality between two quantities with no evident logical connection".

If a scientists' citation and publication data is right-skewed then the h-index will not portray the complete picture. Consider 2 scientists A and B; A has a small number of publications but all are highly cited. While B has a large amount of papers but all are cited very less. Both will have the same h-index. Consider another scientist, whose h publications have h citations each, but this is an unrealistic example as constant performances like this don't occur very often. H-index depicted the incomplete picture of the researchers whose citations and publications have aslant distribution. H-index does not have many limitations and it changes with varying number of citations. The number of citations may change or remain constant as time goes by.

3.11.2 G-index

An extension of h-index, known as G-index is proposed as a measure of citations of research articles. According to Egghe et al.[10] g-index is an index that was projected as a continuation of h-index. It is another author level metric. It measures the importance of best articles by authors. G-index is defined as: "as the highest number g of papers that together received g2 or more citations. From

TABLE 3.2: Citations and Publications of Researcher A and B

Published Papers	**Received Citations**	
	Researcher A	Researcher B
1	60	15
2	44	10
3	38	10
4	32	6
5	6	6
6	2	4
7	1	3
8	-	3
9	-	2
10	-	2
11	-	1
H-index	6	6

TABLE 3.3: Calculation of G Index

No of Published Papers(g)	**Received Citations**	G^2	**Total Citations**
1	20	1	20
2	18	4	20+18=38
3	6	9	38+6=46
4	4	16	46+4=50
5	2	25	50+2=52
6	1	36	52+1=53
7	1	49	53+1=54
8	0	64	54+1=55

this definition, it is already clear that g ¿h". The difference between the two is that g-index gives more value to the paper that has a higher number of citations. To understand the concept of g-index lets consider an example if the researcher whose citations and publications are depicted in Table 3.3.The G-index is calculated by citations are arranged in descending order and are doubled by taking square roots.

The g-index of the researcher will be 7 as this is the point where g2 and the sum of citations are equal. A major positive of g- index is that it outputs a unique largest number. It gives credit to both highly and lowly cited authors. The articles are arranged in descending order based on the number of their citations. And the g-index is the biggest number that the top g number of articles get at least g2 citations. An advantage of g-index over h-index is that credits the paper that has more number of citations. It goes so far as to help in giving credit to papers that have lesser number of citations. It can be established that g-index offers a wide variety and does a good job at researcher ranking. According to the above mentioned formula, the number of citations is doubled due to the square root.

3.11.3 A-index

Impact of a publication can be measured with the total citations it has, the h-index calculates the most impactful subset out of an author's life's work, and this was named as Hirsch Core by Hirsch in 2007. While this observation was made by Burrell in the year 2007 [42].Jin et al [27] more formally defined Hirsch Core as the most highly rated and best publications contained in a set [5]. The a-index is defined by the maximum number of cited papers because it only takes into account, the works contained in Hirsch's core. Because it works with the maximum number of citations, Jin suggested in 2006, that it should be thought of as a variation of h-index. A-index is defined as:

$$A = \frac{1}{h} \sum_{j=1}^{h} C_i t_j \tag{3.1}$$

3.11.4 R-index

A-index punishes the scientists with higher h-index for h gets divided by a-index. Hence, researchers have argued that by taking the square root of the total sum of citations instead of dividing by h. Jin et al. referred to this new index as r-index. R-index calculates the number of citations just like a-index, therefore, it can be very prone to even a few papers that have been highly cited. Jin et al. stated that the a-index divides the h-index by a-index, hence being inherently biased against authors with high h-index values. Jin et al. also proposed a solution to the problem they highlighted. They suggested that instead of dividing by h, the citation sum's square root should be calculated elimented the problem of biasness [8]. This gave birth to r-index.

The calculation mechanism of r-index is exactly the same as a-index hence it can easily be affected by even a small amount of papers that have a lot of citations. Formula to calculate the r-index is:

$$R = \sqrt{\sum_{j=1}^{h} C_i t_j} \tag{3.2}$$

3.11.5 Q2-index

The geometric mean of m-index and h-index gives us the Q2-index. Quantitative analysis is provided by h-index while m-index is a qualitative measure. The h-index (quantitative index) has a vigorous nature and gives insight into the number of papers. While the m-index (qualitative index) because it properly deals with the distributions related to the citation amount. Another reason for its use is that, it helps find the impact that the publications have. This index has behaves as both the qualitative measure as well as quantitative measure. While ranking authors not the most important factor is the quality of the author's work. Hence we can say that this index takes both qualitative and quantitative aspect into consideration, and provides a more complete picture as compared to when either factor is considered alone.

The index is not easily affected by other high values and uses geometric mean to make its derivation easier. So, it gives information in a more coherent and stable form. Cabrerizo et al. defined it as [11]:

$$q^2 = \sqrt{h.m} \tag{3.3}$$

3.11.6 Hg-index

In 2006 Rousseau indicated that the g-index and h-index calculate many aspects of an author's work. But the issue is that neither of them can provide the full picture, covering all the aspects. S. Alonso et al. highlighted that in order to achieve comprehensive results both indices should be taken into account as both focus on calculating separate characteristics of research papers [13]. This idea inspired the birth of Hg-index. The Hg-index minimizes the individual shortcomings of the 2 indices and combines their strengths. The calculation of geometric mean of both g and h-index leads to the Hg-index, so it is defined as:

$$hg = \sqrt{h.g} \tag{3.4}$$

3.11.7 Total No of Publications

In the world of scientific research, an author who has the most publications is considered to be a big contributor [43]. An author is accepted as an expert if he has the largest number of publications [44]. The authors created an expert finding system to rank biomedical experts of India; it also took into account their related subject of study. The system uses the biomedical subject headings (MeSH) for indexing the publications of authors. They did a test-run on known experts and the results were as expected. However, they identified one flaw in their system which is that it all authors of one paper to be experts of the field the paper belongs to, or the MeSH term it is defined by.

For example, consider a paper co-authored by two experts; one of 'biomedical' and the other of 'statistical'. The system would classify the statistical expert as a biomedical expert as well because the paper as a whole is of the biomedical area. A very small number of researches rank researchers by using publication count. One example of such a study is by Yang et al, they created an automatic system that found domain experts by using publication count [45]. The results of their experiments show that their system did a good job of finding experts in some areas. They also mentioned that the limitation of their study is that every publication has a varying degree of importance as compared to the others. This can be overcome by considering the impact factor of a publication.

A different idea is to not use the publication to rank authors. One implementation is by Codd on a relational database. 49 articles are written by Codd and 248 by Hector. In ranking experts based on publication count, Hector would perform much better than Codd. Even though the effect of Hector's work is less than Codd's. This is because Codd created the relational database model, ranking Hector above him will not be acceptable by the scientific community [3]. Hence we can say that it is not must for publication count to cover the impact and quality of work. The number of publications can be found by the below mentioned formula; where paper number is represented by pi. In this approach, the author with most papers written will be ranked on top. The publication count is defined as:

$$P_{ub}Count = \sum_{j=1}^{n} P_i \tag{3.5}$$

3.11.8 Citation Count

Citation count was proposed as an answer to the limitations of publication count. Both the quantity and quality of research can be measured by citation count. In combination with bibliometric information, citations play an important role in author ranking [46]. It expresses an author's impact in the area of this research work. If the citation count of all publications of a particular author is more than the others, then that author is ranked high.

A comparative study was done on the data from American Physical Society by [16]. The comparison was between simple citation count and some graph based algorithms, to determine which approach leads to better author ranking. They concluded that the results from citation count were better than those of graph based algorithms. This research also pointed out the important fact that citation count has limitations and is not enough to rank authors mainly because author importance is not static, it is dynamic. Citation count fails to mention the reasons why a paper has the number of citations it has. The reasons matter because sometimes work is cited only to be criticized, but it does increase the total number of citations [47]. The formula to compute citation count is:

$$C_{it}Count = \sum_{i=1}^{n} C_{it}P_i \tag{3.6}$$

3.11.9 M-Quotient

Taking the career length issue into consideration, Hirsch brought forward the m-quotient or Hirsch's m quotient in his original work, where he also introduced h-index. Burrell et al. highlights that career length and the h-index have an approximate proportion [42]. To get a comparison of the author and length of career, we divide the h-index by the years since first publication [42]. The formula to compute m-quotient is:

$$M - quotient = \frac{h}{y} \tag{3.7}$$

'H' is the h-index and 'y' denotes the years since the first paper was published. Hence, m-quotient proves to be useful in situations where one needs to analyze authors who have varying career lengths. The major advantage of m-quotient is that if a writer discontinues publishing for some time, their h-index will continue to decrease

3.11.10 AR-Index

The AR-index not only makes use of the actual amount of articles'(from h-core) citations, it also considers the age of publication. The ar index is defined as the sum of the average number of citations per year of articles included in the h-core [27]. Moreover, the h-index is defined by an index that has the capability to decrease. This is a necessary quality for an efficient evaluation indicator. Jin et al. consider that an efficient indicator must be sensitive to changes in performance. Hence, the (h, ar) pair is suggested as a practical indicator for evaluation of research papers. Since the definition of h remains constant, only 1 element of the pair has the ability to decrease. This index has the ability to both increase and decreases with time. To compute the ar-index the formula is:

$$AR = \sqrt{\sum_{j=1}^{h} \frac{C_i tp}{ap}} \tag{3.8}$$

The square root of the sum of the average of citations per year of all articles that are also in the h-core is referred to as the AR-index. The ar-index has 3 factors; h-index (represented by h), p stands for the publication, citation count (cit), years since publication (ap). Ar-index aims to remove the bias towards the authors that have not published for some time because the h-index does not decrease with periods of inactivity. It remains the same, even in the worst case. The name AR-index indicates that this index depends on the age and is evaluated by taking a square root.

3.11.11 M-Index

It is defined as the median of the citations of the papers that are a part of the Hirsch core. It is a ranking for the paper that is either smaller than or equal to h. The measure of central tendency should be the median, as opposed to the average because citation counts tend to be skewed. Hence, we introduce a variation of a-index; the m-index- [5] the median citations of the papers included in the Hirsch core.

3.12 Evaluation

After creating the lists where authors were ranked, the discussion and analysis of previously mentioned research questions are presented. After data collection and cleaning, we calculated 11 parameters on data, "Appendix A" shows the calculation of these 11 parameters. After the calculation of parameters, we have separately ranked the authors according to each index. After this step, we get 11 distinct rankings of authors which are further evaluated based on four research questions postulated in this study.

3.12.1 Correlation Calculation of Ranking Parameters

Firstly the question to be answered is: 'is there actually some correlation between the parameters'. The answer to this question will indicate the similarities that the indices have. The second question is to find out such examples where these parameters perform in a non-repetitive way.

Correlation coefficients describe the degree to which two different variables are associated. Specifically, the magnitude and direction of the association is depicted by the correlation coefficients. A Pearson Correlation describes the degree to which two normally distributed random variables are associated linearly. Spearman correlation rank is a non-parametric test used to determine the extent of association between two variables.

We have used spearman correlation rank to measure correlation between primitive parameters, publication age based and citation intensity based parameters because it is anticipated that the standing of a researcher in quantitative rankings, i.e., the number of publications is not stringently related in a linear fashion to his or her position in our qualitative scoring. The spearman rank correlation describes a monotonic relation between 2 variables and the test is non-parametric i.e. it doesnt involve any suppositions about the distribution of data. It is the suitable correlation analysis when dealing with variables that are measured on a scale that is at least ordinal. Spearman's rank correlation can find correlations among the indices, according to Corder and Foreman [48] formula to compute the correlation is:

$$P = 1 - \frac{6\sum_{i=1}^{n} d^2}{n(n^2-1)} \tag{3.9}$$

3.12.2 Determine the Trend of Awardees

After calculating the list of highly ranked authors, we will find out if the top 10% of global awardees from the Mathematics field are in it or not? We will also conclude that which parameter has contributed the most in bringing the awardees to the top of the list. To get the required answers, we must find the number of people who are in the top 10% and also find how many awardees fall in 1-10%, 11-20% and so on. An analysis of the manifestation of awardees in the top 100, 500, 1000 authors was also performed. After that, all researchers were individually ranked. Then, the positions of awardees in the list are determined. Next, we determined the award winners that fall in the top ten percent, and in the same way for the entire ranked list, we found the awardees' occurrences. For example, given a list containing 100 authors, from a particular dataset, 20 authors from the said list are award winners. The names of the authors will be arranged in descending order. Then 10% of the data set is extrapolated. This means that 10% of data contains information of the 10 authors that we included in the top 10. Suppose, there are 4 occurrences in the top 10% award winners. Hence, in this example, 20% of the award winners will be considered to be in the top 10% researchers, this would be based on the index values.

3.12.3 Performance of Mathematical Awards Societies between different Parameters

In this section, the third question will be the focus. The question is to find out how the parameters perform differently based on different award bestowing societies like AMS, IMU, LMS, and NASL. To accomplish this take, we first have to determine the frequently occurring award winners in the top 10 percent of the ranked list of best researchers. We had calculated the percentage of award winners that occur in the top 10 percent of the ranked list previously. Now, we calculate the same but with the award winners from 1 society; how many winners of this society are in the top 10%? For example, let there are 350 award winners from IMU belonging to the Mathematics domain. Consider that from those 350 names, the 10% present in the list ranked based on g-index, makes 151 names. So, in this situation, the top 10 percent of the created list, 42% belong to IMU based on the g-index.

3.12.4 Ranking of Parameters for Classification

The last research question is to rank the parameters which can best classify the awardees and non-awardees of prestigious awarding societies. The purpose of classification is to determine which ranking parameter performs well for classification of awardees and non-awardees. To rank the parameters we have used binary classifier because our dataset has a binary class. Each classifier has its own merits. We have used Nave Bayes, k-Nearest Neighbors (k-NN), and Support Vector Machine (SVM), machine learning classifiers. These classifiers are chosen for use based on their popularity in the literature that deals with the classification of ranking [49, 50]. Chapter 4 presents the detail of the results of each classifier. WEKA, a renowned Machine Learning environment is used for the classification.

3.12.4.1 Naive Bayes Classifier

A group of probabilistic classifiers knows as the Naive Bayes classifiers; they consider naive (strong) assumptions between characteristics and apply the Bayes' theorem. These classifiers were first studied in the 1960s when they were applied to text retrieval; though they were not referred to by this time name at that time [51]. They still have many useful applications like text categorization, document classification problem (based on categories like useful or spam, news or games), using the frequency of words as features. Provided with adequate preprocessing, they can compete with high-end techniques like support vector machines. Automatic diagnosis is a medical application of these classifiers.

A straightforward classifier that applies the Bayes formula to match dataset labels to proper labels is called the Naive Bayes [52]. A pre-condition for such calculation is that the characteristics must not statistically depend on each other for the corresponding target label. Many experiments reveal that a small-sized training data set is sufficient to train the Naive Bayes. It has higher runtime performance than other classifiers and it is very easy to adjust its parameters.

The extremely scalable nature of Naive Bayes classifiers means that the learning problem must have several linear parameters and variable predictors or features. Many classifiers use iterative approximation, which can be costly, whereas the Naive Bayes classifier evaluates closed-form expression, and can easily achieve maximum-likelihood learning in linear time.

Naive Bayes classifier is known by different names in the scopes of computer science and statistics, for example, independence Bayes and simple Bayes. The use of such names indicates that the classifier uses Bayes' theorem in the decision rule; however, Naive Bayes does not need to be a Bayesian method.

3.12.4.2 k-Nearest Neighbors Classifier

Regression and classification can also be done in a non-parametric way by using the K-Nearest Neighbors algorithm (k-NN). k-NN is the most simple machine learning algorithm.The scalable nature of this classifiers means that the learning problem must have several variable predictors or features. The input is the same for both parametric and non-parametric; k closest training examples. The output varies based on whether the implementation is for regression or classification.

k-NN is a lazy or instance-based learning algorithm. The class membership is the output produced by k-NN classification. The neighbors of an object decide its classification by plurality vote; hence the object gets allocated to the class that is the most among its k neighbors. K is any positive number, which generally has a small value. The object is allotted to the nearest neighbor if the value of k is 1.

In k-NN all the calculations before the final classification are adjourned, the approximation of the function is done only locally; these characteristics ensure that k-NN is a kind of lazy or instance-based learning [53].

3.12.4.3 Support Vector Machine Classifier

Supervised learning models known as support vector machines are equipped with algorithms of associated learning that allow the analysis of data which is used for regression and classification. The SVM works in the following way; some training examples along with the categories they belong to are fed into the SVM, it then applies its algorithms to create a model. This model has the ability to categorize new examples. Hence an SVM is a binary non-probabilistic, linear classifier [54].

The SVM model visualizes the example as points in space, all the points are mapped to the category they belong to, and so the different categories have a distinct and wide gap between them. When a new example arrives, the distance of it's from the gap is measured and its category is predicted based on this distance. SVMs are not just limited to linear classification; the kernel trick enables them to do non-linear classification. The kernel trick implicitly maps its inputs to feature high-dimensional spaces.

3.12.4.4 Classifiers Performance Evaluation Metrics

We have calculated Recall, Precision, and F-measure to determine the performance and accuracy of each classifier. The general formulae of F-measure, Recall, and Precision are used for evaluation. 10-fold cross-validation is used by the Nave Bayes, SVM, and k-NN for classification. These classifiers are chosen for use based on their popularity in the literature that deals with the classification of citations as non-important or important [49, 50].

Classification based on individual metadata parameters helped in gaining insight regarding how much contribution each parameter makes towards the most optimal results. The abovementioned classifiers are used to evaluate the Recall, Precision, and F-measure, while the average F-measure, Recall, and Precision are calculated by taking the arithmetic, mean of the 3 classifiers. The formulas to calculate the Recall, Precision, and F-measure are depicted in equation 3.10, 3.11, and 3.12 respectively

$$Recall = \frac{TruePositve}{TruePositive + FalseNegative} \tag{3.10}$$

Recall determines how much the relevant results have been retrieved out of the relevant results.

$$Precision = \frac{TruePositve}{TruePositive + FalsePositive} \tag{3.11}$$

The precision determines how many results which are classified correctly for a class.

$$F - Measure = 2 * \frac{Precision * Recall}{Precision + Recall} \tag{3.12}$$

The Recall and Precision are combined into one measure by F-measure. We have discussed the detailed result of this research question in chapter 4.

Chapter 4

Results and Evaluation

This chapter explains the results obtained by implementing the methodology as explained in chapter 3 which was adopted to examine the capability of different experts ranking parameters and their possible contributions in the ranking of researchers.

4.1 Assessment of Correlation between Ranked Lists

This evaluation is done to find out the similarities between the ranked lists. To find the answer of the 1st research question we must determine the correlation between all indices. To accomplish this, we found out the correlation of each list with all the other ranked lists. Correlation values can either be positive, negative or 0. Positive shows direct relation, which means an increase in 1 value causes an increase in the other. Negative value shows inverse relation i.e. increase in one value signals decrease in the other. Zero means that there is no correlation between the lists i.e. they are independent. The magnitude of the correlation value tells the intensity of the relation. In Table 4.1 the scrupulous set of correlation values of ranked lists generated from the primitive parameters and publication age based parameters is presented. In Table 4.2 the correlation among primitive and citation

Table 4.1: Correlation between Primitive and Publication Age Based Parameters

	H-Index	Total-Publications	ARIndex	Total-Citation	M-Quotient
H-Index	1	0.9	0.03	0.3	0.05
Total-Publications	0.9	1	-0.004	0.218	0.01
AR-Index	0.03	-0.004	1	0.61	0.28
Total-Citations	0.3	0.218	0.61	1	0.02
M-Quotient	0.049	0.01048	0.279	0.024	1

intensity based parameters is represented, and in Table 4.3 the correlation among citation intensity and publication age based parameters is depicted. Tables 4.1, 4.2 and 4.3 show the full range of values. The parameters' correlation with itself is 1.

The results of Table 4.1 indicate that strong correlation values overpower the weak ones. The h-index has a strong correlation with 4 parameters, while it has a weak correlation with 3 parameters. It also has a negative correlation with 2 parameters. Overall, the strong correlation is more than the weak one between primitive and citation intensity based parameters. It is evident from table 4.2 and 4.3 that weak and negative correlation values among publication age, and primitive parameters, and citation intensity and publication age based parameters overpower the strong one.

Figure 4.1 depicts the correlation between primitive and citation intensity based parameters. We can see that h-index has a strong correlation with hg-index, q2-index, author total publication, g-index, and with total citation, ar-index, m-quotient, a-index, and r-index it has week correlation. H-index ranked list depicts the negative correlation with m-index. Figure 4.2 depicts the correlation of authors total publication with all other parameters.

TABLE 4.2: Correlation of Primitive and Citation Intensity Based Parameters

	H-Index	Total-Publications	M-Index	Total-Citation	A-Index	G-Index	HG-Index	Q2-Index	R-Index
H-Index	1	0.9	-0.02	0.3	-0.01	0.949	0.988	0.907	0.457
Total-Publications	0.9	1	-0.03	0.218	-0.01	0.985	0.967	0.942	0.358
M-Index	-0.02	-0.03	1	0.7	0.974	-0.04	-0.0348	-0.027	0.572
Total-Citations	0.3	0.218	0.7	1	0.78	0.23	0.249	0.246	0.827
A-Index	-0.007	-0.0149	0.974	0.78	1	-0.013	-0.01	0.322	0.648
G-Index	0.949	0.985	-0.04	0.23	-0.01	1	0.984	0.948	0.391
HG-Index	0.988	0.967	-0.0348	0.249	-0.01	0.984	1	0.936	0.433
Q2-Index	0.907	0.942	-0.027	0.246	0.322	0.948	0.936	1	0.416
R-Index	0.457	0.358	0.572	0.827	0.648	0.391	0.433	0.416	1

Table 4.3: Correlation of Citation Intensity and Publication Age Based Parameters

	AR-Index	M-Index	M-Quotient	A-Index	G-Index	HG-Index	Q2-Index	R-Index
AR-Index	1	0.718	0.28	0.745	-0.02	-0.0089	0.0083	0.749
M-Index	0.718	1	0.02	0.974	-0.04	-0.0348	-0.027	0.572
M-Quotient	0.279	0.023	1	0.006	-0.015	-0.014	0.044	-0.021
A-Index	0.745	0.974	0.01	1	-0.013	-0.01	0.322	0.648
G-Index	-0.02	-0.04	-0	-0.01	1	0.984	0.948	0.391
HG-Index	-0.008	-0.034	-0	-0.01	0.984	1	0.936	0.433
Q2-Index	0.0083	-0.027	0.04	0.322	0.948	0.936	1	0.416
R-Index	0.749	0.572	-0	0.648	0.391	0.433	0.416	1

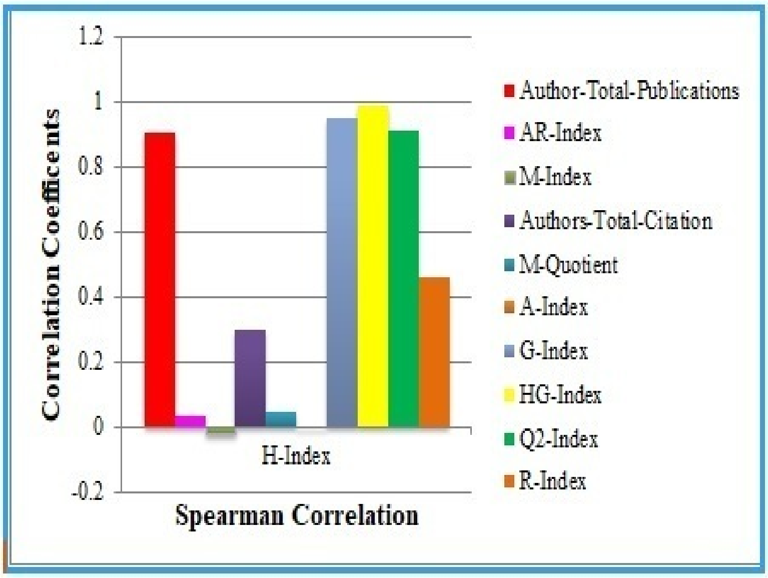

FIGURE 4.1: Correlation of H-index with all other parameters.

The behavior of authors total publication parameter is almost similar to h-index. It has a strong correlation with hg-index, q2-index, h-index, g-index and with authors total citation, m-quotient and r-index it has week correlation. Authors total publication ranked list depicts the negative correlation with ar-index, m-index, hg-index, and q2-index. r-index ranked list depicts the negative correlation with m-quotient.

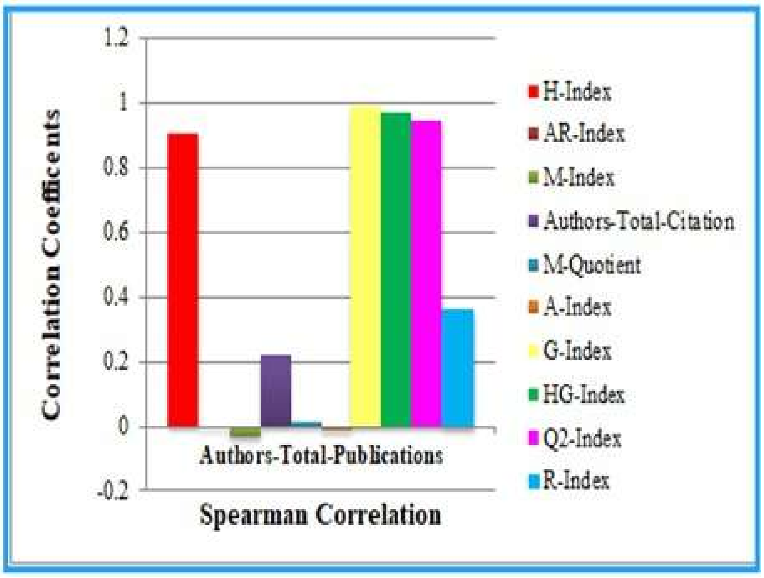

FIGURE 4.2: Correlation of Authors Total Publication with all other Parameters.

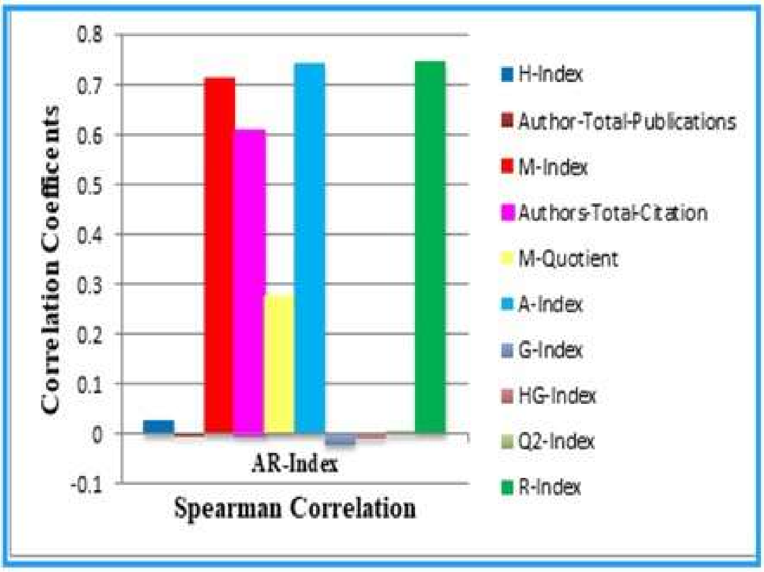

Figure 4.3: Correlation of AR-index with all other parameters.

Figure 4.3 depicts the correlation of ar-index with allother parameters. We can see in the figure that the ar-index has a strong correlation with r-index, m-index, a-index, and authors total citation, and with h-index, m-quotient and q2-index it has week correlation. The ar-index ranked list depicts the negative correlation with the author's total publication, g-index, and hg-index.

Figure 4.4 depicts the correlation of g-index with all other parameters. We can see in the figure that the g-index has the same behavior as h-index it has a strong correlation with h-index, hg-index, q2-index, and authors total publication. The g-index ranked list depicts the negative correlation with ar-index, m-index, a-index, and m-quotient and with total citation and r-index it has a weak correlation.

Figure 4.5 depicts the correlation of m-index with all other parameters. M-index has a strong correlation with ar-index, a-index, and author's total citation and with m-quotient and r-index it has week correlation. M-index ranked list depicts the negative correlation with the author's total publication, h-index, q2-index, hg-index, and g-index.

Figure 4.6 depicts the correlation of authors total citation with all other parameters. Authors total citation has a strong correlation with ar-index, m-index, a-index, r-index and with authors total publication, h-index, m-quotient hg-index,

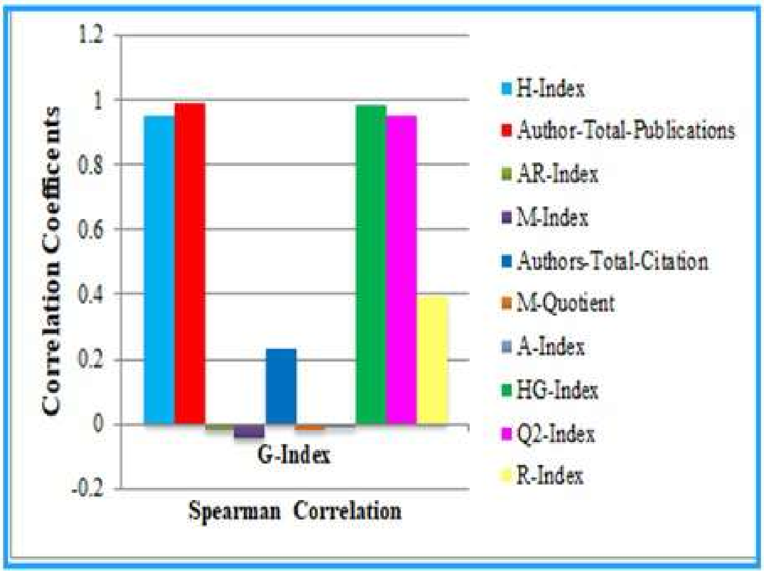

FIGURE 4.4: Correlation of G-index with all other parameters.

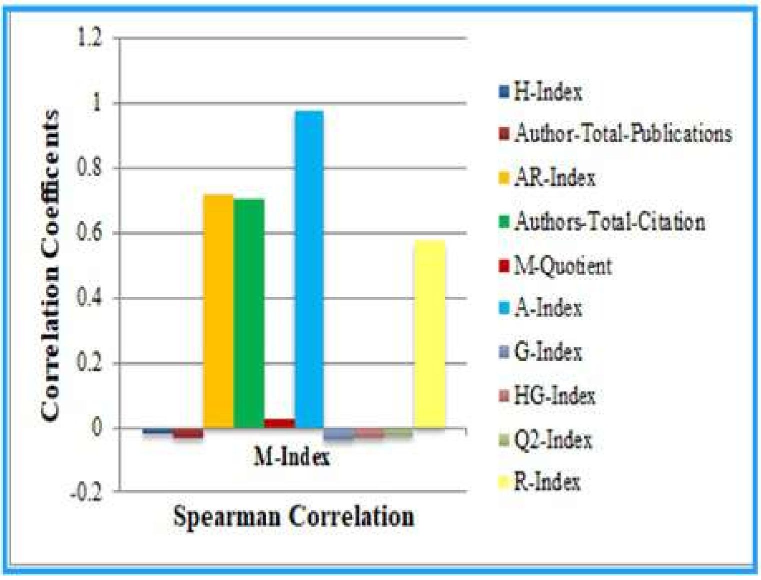

FIGURE 4.5: Correlation of M-index with all other parameters.

q2-index and g-index it has week correlation. Authors total citation ranked list depicts that it has no negative correlation.

Figure 4.7 depicts the correlation of a-index with all other parameters. A-index has a strong correlation with ar-index, m-index, r-index, and author's total citation, and with m-quotient, and q2-index it has week correlation. A-index ranked list depicts the negative correlation with the author's total publication, h-index, g-index, and hg-index. Figure 4.8 depicts the correlation of hg-index with all other

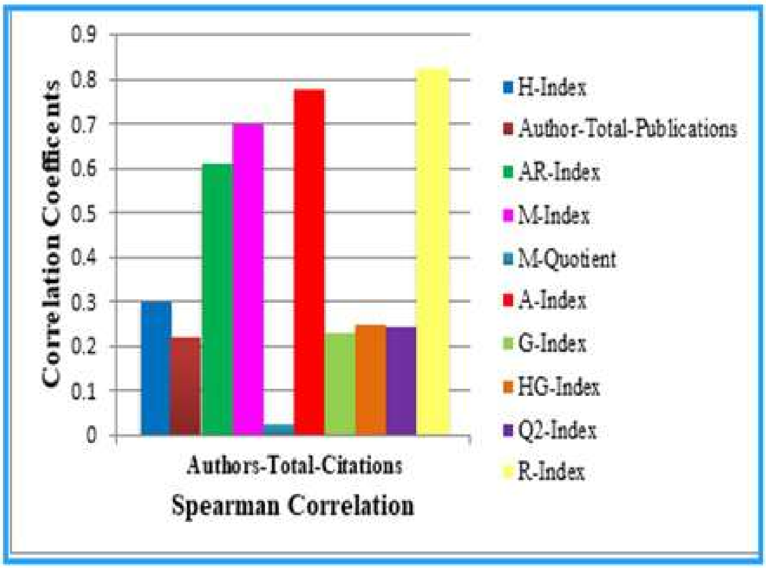

FIGURE 4.6: Authors total citations.

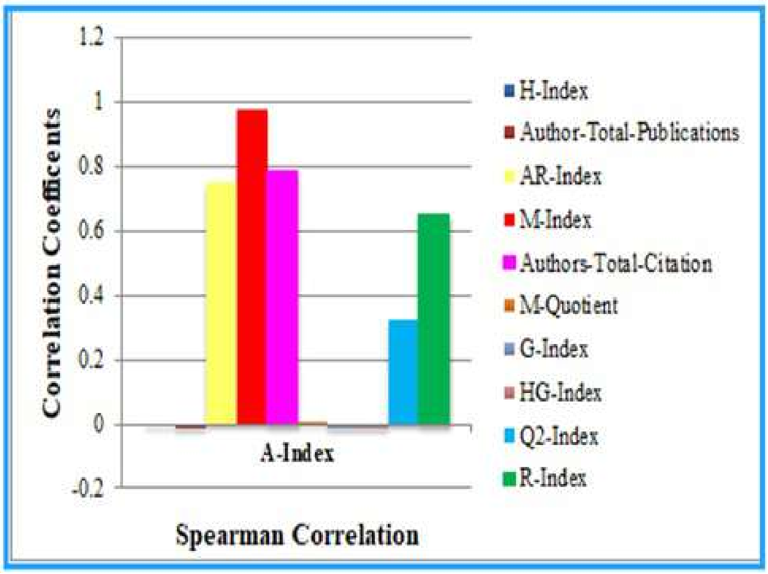

FIGURE 4.7: Correlation of A-index with all other parameters.

parameters. It has a strong correlation with the author's total citation, m-index, ar-index, and r-index and it has week correlation m-quotient, and q2-index.
A-index ranked list depicts the negative correlation with hg-index, h-index, g-index and authors total publication. Figure 4.9 depicts the correlation of q2-index with all other parameters. It has a strong correlation with h-index, hg-index, g-index and with authors total publication. Q2-index ranked list depicts the weak correlation with authors total citation, r-index, ar-index, a-index, and m-quotient, and it has a negative correlation with m-index. Figure 4.10 depicts the correlation of

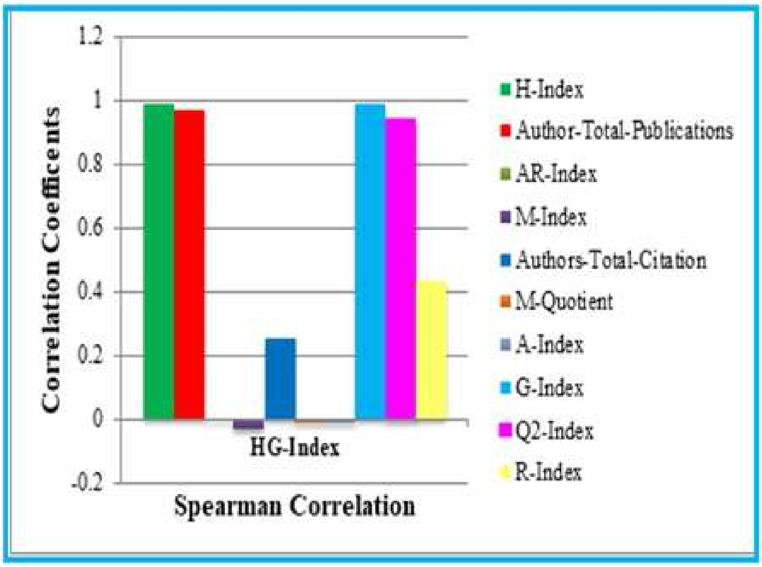

FIGURE 4.8: Correlation of HG-index with all other parameters.

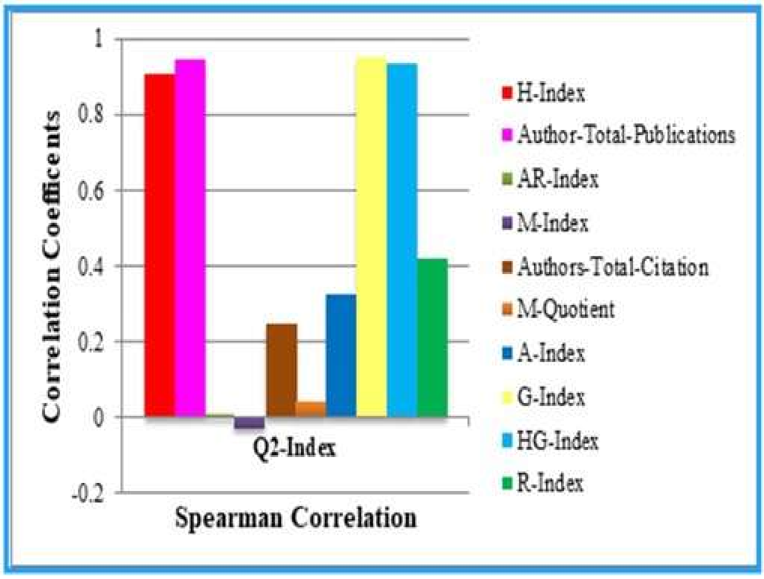

FIGURE 4.9: Correlation of Q2-index with all other parameters.

r-index with all other parameters. It has a strong correlation with ar-index, authors total citations and a-index, and it has week correlation with h-index, authors total publications, m-index, g-index, hg-index, and q2-index. R-index ranked list depicts the negative correlation with m-quotient. Figure 4.11 depicts the correlation of m-quotient with all other parameters. It has a weak correlation with the author's total publications, q2-index, h-index, g-index, authors total citation, ar-index. M-quotient ranked list depicts the negative correlation with g-index, hg-index, and r-index. The results of the first research question pave the way to

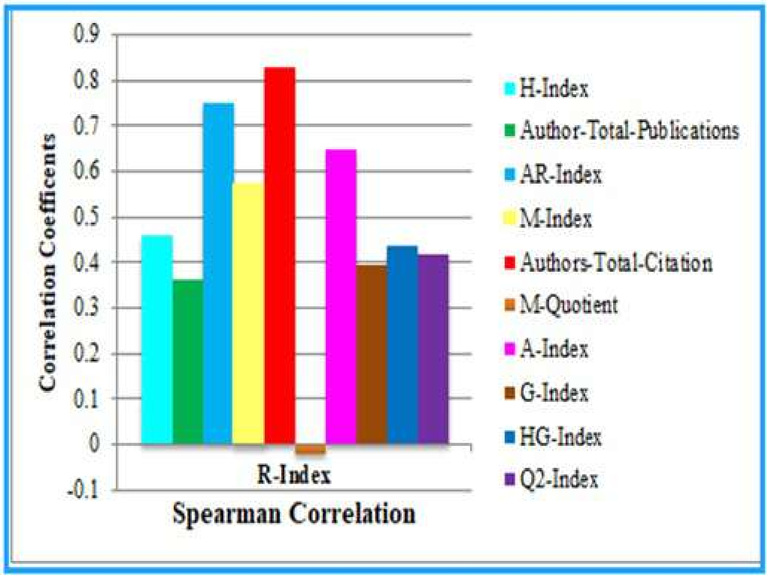

FIGURE 4.10: Correlation of R-index with all other parameters.

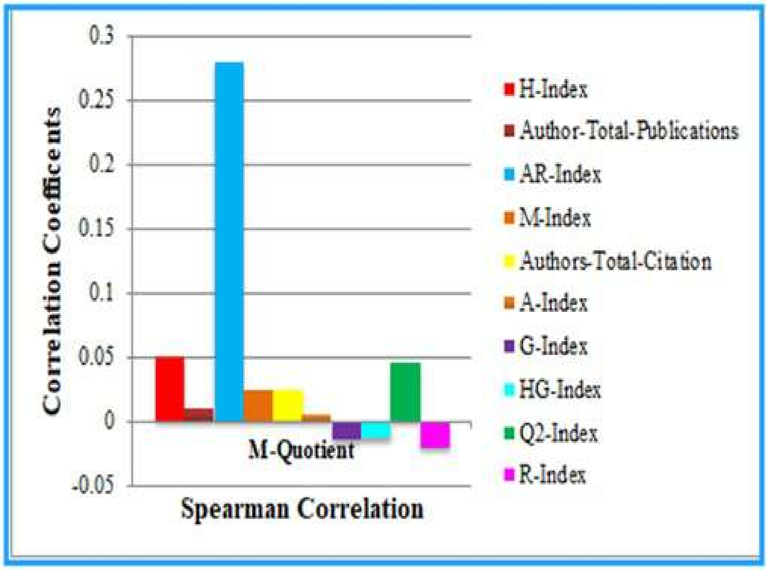

FIGURE 4.11: Correlation of M-quotient with all other parameters.

the next questions

4.2 Awardees Trend in the Author Ranked Lists

This section deals with answering the 2nd and 3rd research question. We have analyzed the role each index plays in getting the award winners that are at the top of the list, and have also found out how many times the awardees occur in the top of the ranked list. We scanned the top 10% of the list (shown in figure 4.12) and scanned the names of award winners against the parameters. It can be concluded that 31.2%, the maximum occurrences, are present in the top 10 percent of researchers, gathered using the total publications parameter. To answer the second research question following are some observations which have been made from figure 4.12.

- From Figure 4.12 it can be perceived that maximum occurrences of award winners (around 31.2%) lie in the top 10% authors, acquired by the author's total publication parameter.
- The h-index performance is quite the same as the author's publication parameter as it succeeds in retrieved 30.80% award winners at the top. It is evident from figure 4.12 that the author's publication and h-index are the basic metrics for determining the experts in the research world. However, just like all other parameters, the h-index is affected by the duration of a career. Keeping this in mind, the h-index should only be applied in situations where the authors are of similar age and belong to the same field of study. It should be known that all such calculations are not exactly accurate due to the fact that a scientist's entire career and his accomplishments cannot be simply converted to a number. This idea is well expressed by Ziman: "A scientific paper does not stand alone; it is embedded in the literature of the subject" It is also notable that the calculation of publication count and h-index is time consuming and difficult as citations required a long period.
- The author's publication parameter is slightly better than h-index and able to achieve the award. Anyhow, such findings should be verified on a complete dataset of mathematics and if the results are same then we can say that the publication count can be considered as an adequate metric for author's ranking.
- The performance of g-index and hg-index is same.
- The ar-index performance was lower than all other indices.

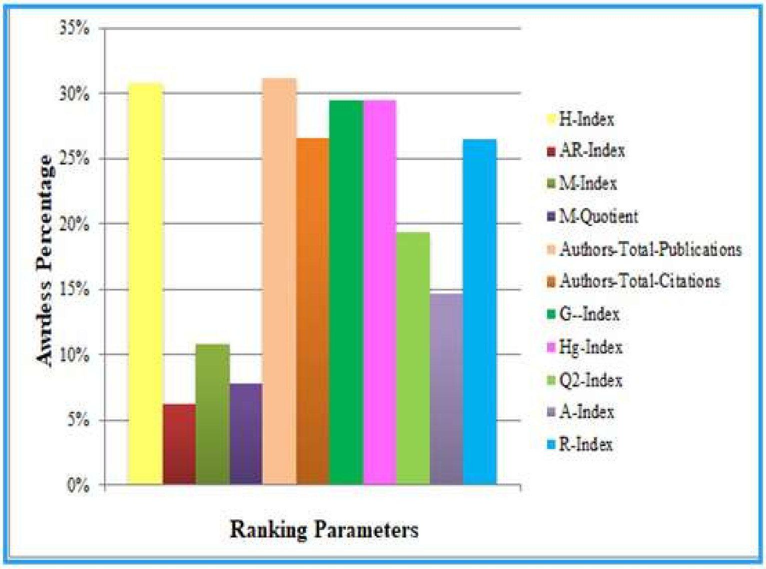

FIGURE 4.12: Award winner percentage in the top 10% of the list.

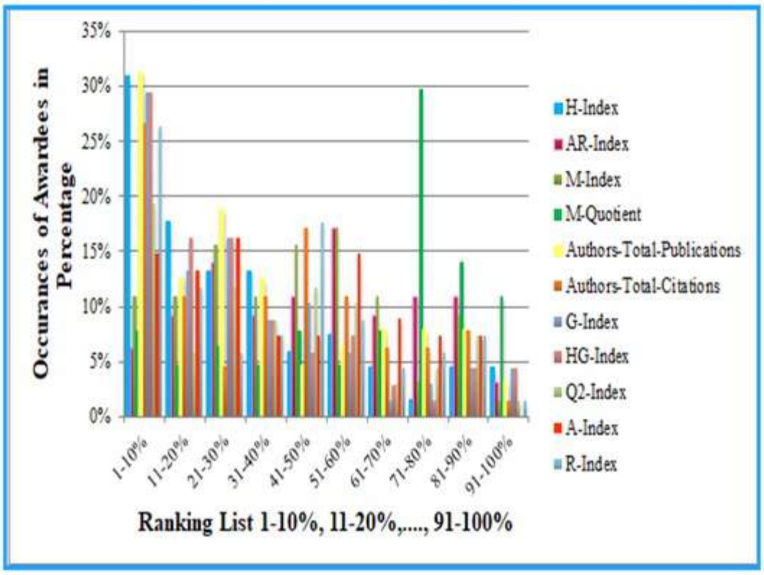

FIGURE 4.13: Awardees ercentage in the top 1-10%, 11-20% of ranked lists.

Next, we checked how many award winners were present in 1-10%, 10-20% so on, till 90- 100% of the entire ranked list that was created by evaluation of all the indices shown in figure 4.13. It is evident from this figure that most of the awardees are present in the top 10% of the generated ranked list. H-index and the author's total publication performance was better than all other parameters in the top 10% of the ranking list. In 11-20% and 31-40%, h-index performed well as compare to other indices and author's total publication metric performed well in 21-30% of the ranked list. The performance of total citation and r-index is better

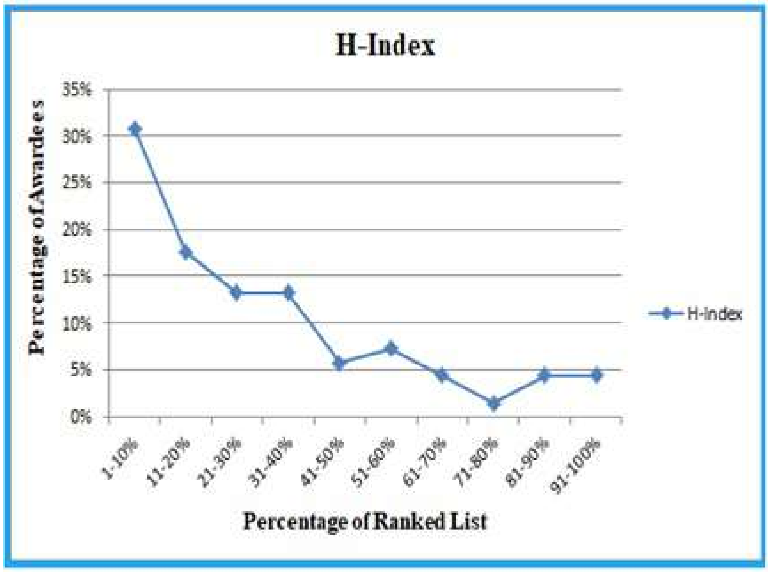

FIGURE 4.14: H-index trend.

as compared to other indices in 41-50%. From 41-50% onwards the performance of these indices is almost the same.

The trends of awardees occurrences in ranking lists have been depicted from figure 4.14 to figure 4.24. The occurrences of the awardees in the top 10 percent has been shown here. Figure 4.14, 4.15, and 4.15 depicts the trend of h-index, hg-index, and g-index. These parameters curve is linear and decreases slowly. While the curves of other parameters are not linear they decrease with a slight increase and decrease at certain points as displayed in figure 4.17, 4.18, 4.19, 4.20, 4.21, 4.22, 4.23, and 4.24.

4.3 The Prestigious Award Societies Decencies on Indices Results

The next question of our research is to determine which award giving society Next we answer the question which awarding society, uses which index the most. To find the answer, we studied the presence of award winners present in the top 10% of our list. The dataset benchmark contains 68 awardees, 29 of which belong to AMS, 23 to LMS, 6 to IMU, and 12 to NASL. It is generally assumed that

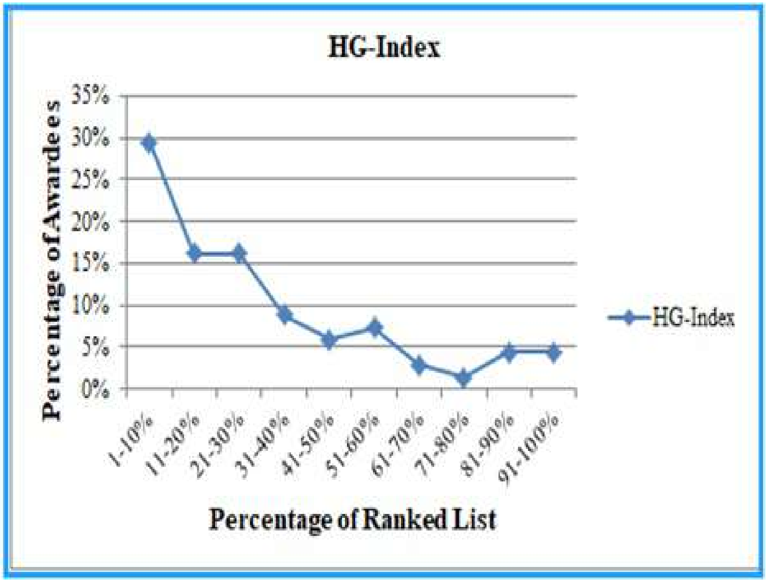

FIGURE 4.15: Hg-index trend.

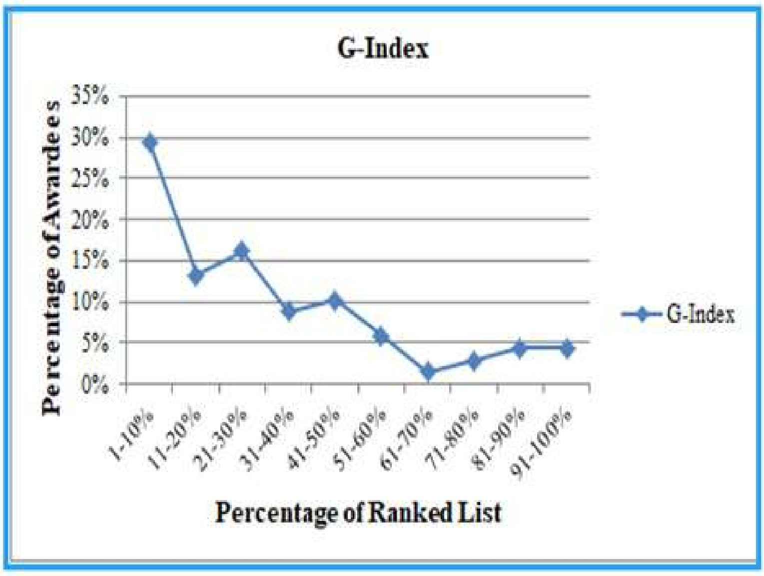

FIGURE 4.16: G-index trend.

the total citations and amount of publications of an award winner will be high, indicating the author's strong background in research. But some cases show that this assumption is invalid. We calculated the behavior of all awarding societies individually, in retrieving the awardees from ranked lists.

Figure 4.25 and 4.26 depicts that 42.6% (29) awardees were brought by AMS, 8.82% (6) by IMU, 33.8% (23) by LMS and 11.76% (8) by NASL. Figure 4.27 clearly shows that which award giving society is well-suited to which parameter. Not only did we evaluate parameters individually, but we also evaluated each

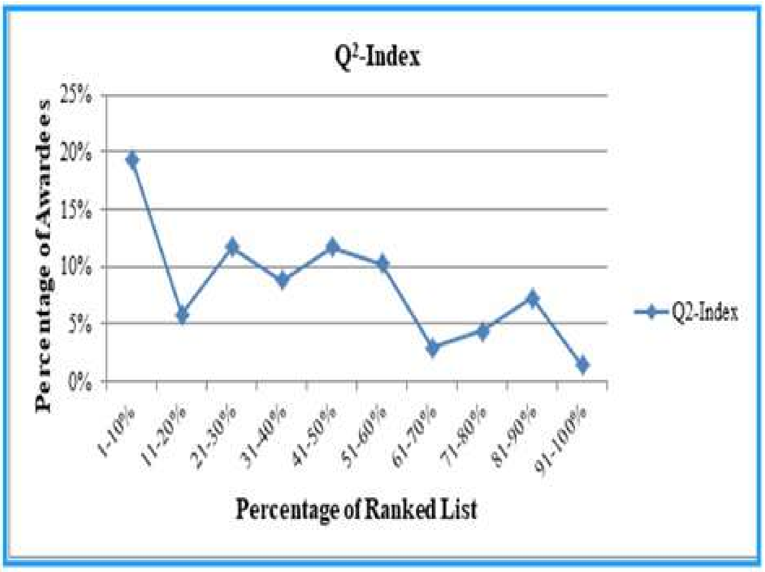

FIGURE 4.17: Q2-index trend.

FIGURE 4.18: Ar-index trend.

society's performance separately. The behavior of awarding societies for every ranking parameter is determined here. The results of our research are given below:

4.3.1 AMS

(a) In AMS the authors total publications performance was better than all other parameters.

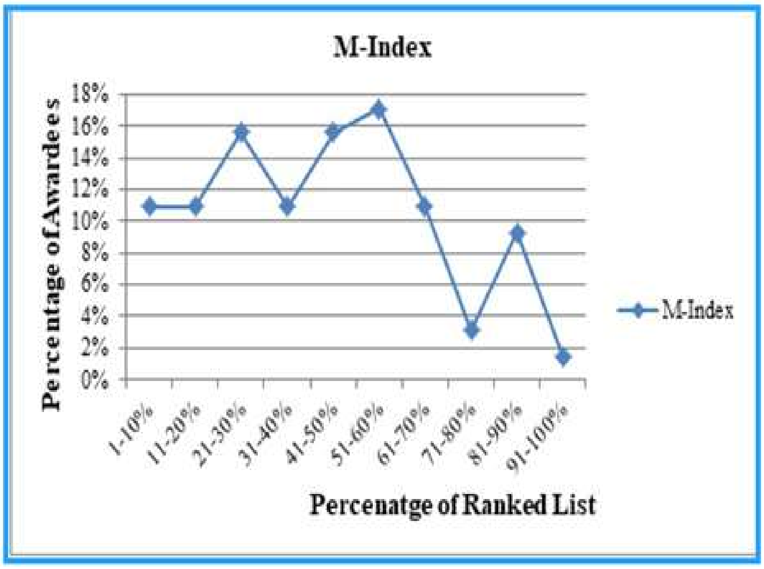

FIGURE 4.19: M-index trend.

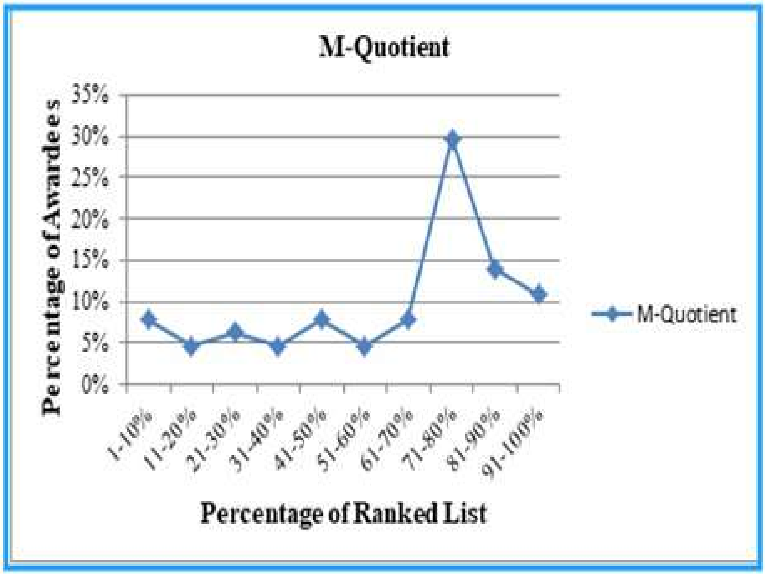

FIGURE 4.20: m-quotient trend.

(b) Theq2-index, hg-index, h-index, and g-index perform well, they all show equal performance: 37.93%.

(c) The r-index performed up to 34.38%.

(d) The m-index, however, shows poor performance (1.30%).

FIGURE 4.21: Author's total publication parameter trend.

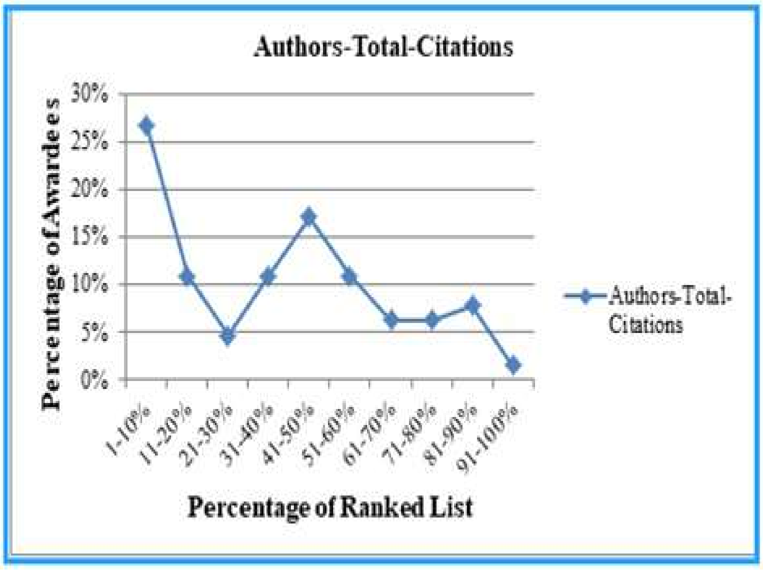

FIGURE 4.22: Author's total citation parameter trend.

4.3.2 IMU

(a) The authors total publication, g-index, hg-index have equal performance, almost 33.33%.

(b) The performance of q2-index and h-index parameters is equal (33.30%)

(c) The performance of m-quotient was poor as it was not able to bring any awardee at the top of the ranking list.

FIGURE 4.23: A-index trend.

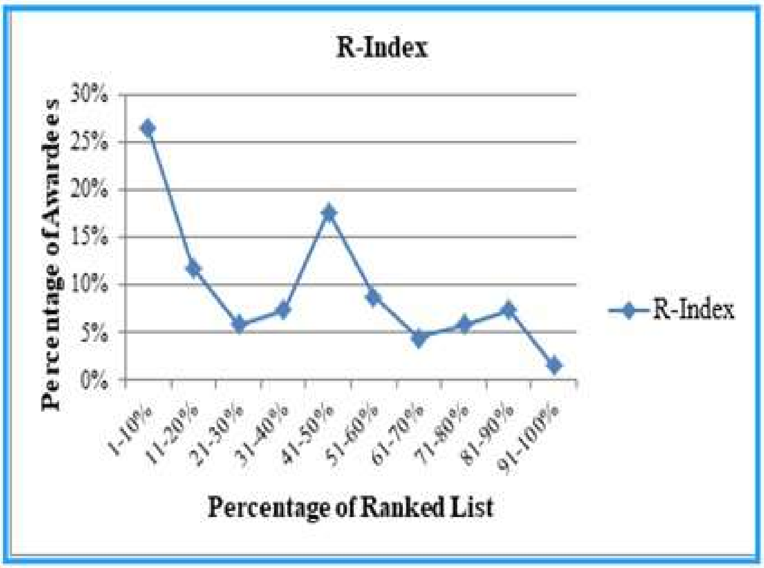

FIGURE 4.24: R-index trend.

4.3.3 LMS

(a) The best performance was of h-index (approx. 21.73%).

(b) While q2-index, g-index, hg-index performed equally (approx. 17.39%).

(c) A-index and r-index had a lesser performance percentage of 13.04%.

(d) The performance of m-quotient was poor as it was not able to bring any awardee at the top of the ranking list.

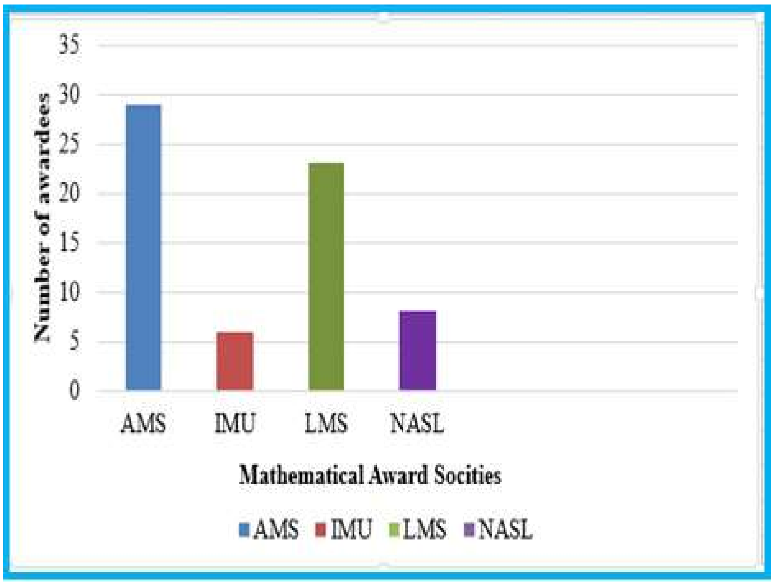

FIGURE 4.25: Total number of awardees retrieved from awarding societies.

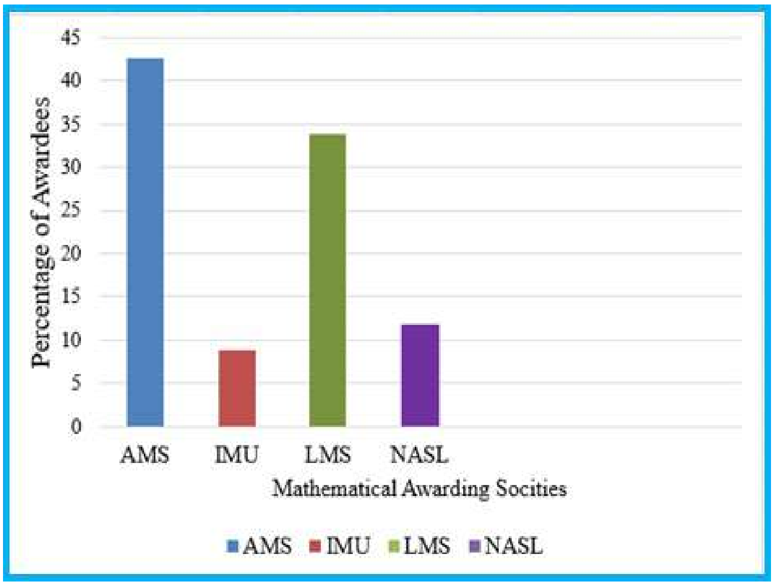

FIGURE 4.26: Awardees percentage retrieved from awarding society in the ranked lists.

4.3.4 NASL

(a) The performance of the author's total publication, h-index, hg-index, author's total citations, g-index, and r-index approx. 37.50%.

(b) The r-index was able to retrieved approximately 37%.

(c) While q2-index, a-index, and m-quotient performed equally as they have retrieved approximately 25%.

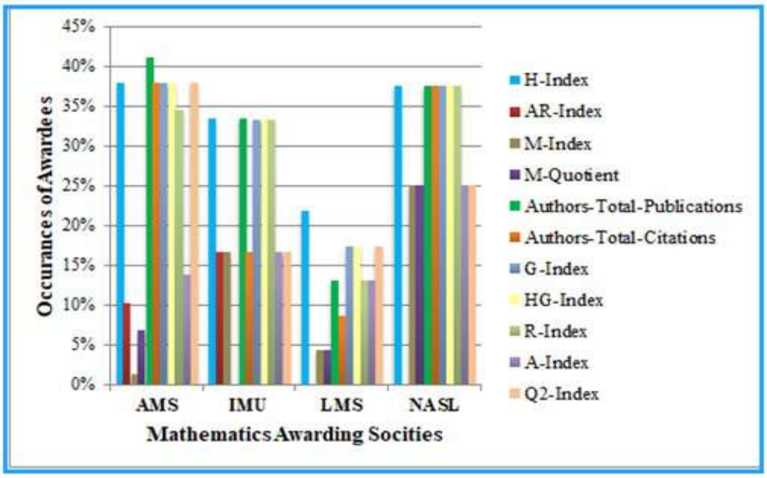

FIGURE 4.27: Trend of ranking parameters on awardees societies.

FIGURE 4.28: Trend of ranking parameters in AMS.

FIGURE 4.29: Trend of ranking parameters in IMU.

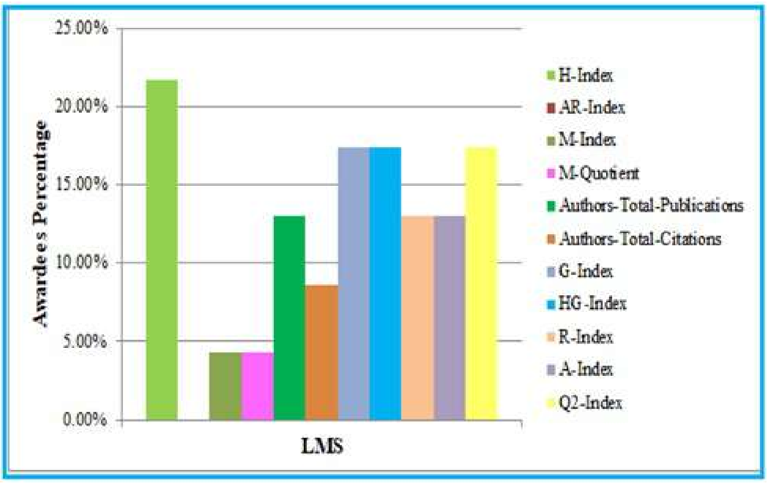

FIGURE 4.30: Trend of ranking parameters in LMS.

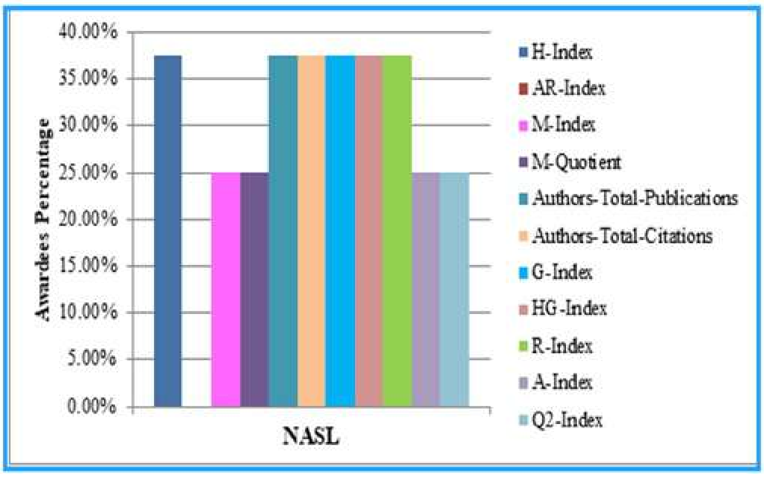

FIGURE 4.31: Trend of ranking parameters in NASL.

(d) The performance of ar-index was poor as it was not able to bring any awardee at the top of the ranking list.

4.4 Award Winners Evaluation in Top-ranked Authors

We studied the top 1000, 500, 100 ranked authors and noted the occurrences of awardees in the lists.The percentages of the award winners present in the highly ranked authors are displayed in figure 4.32. Only 10.29% awardees were brought into the top 100 by the parameters that were under study, the percentage changes

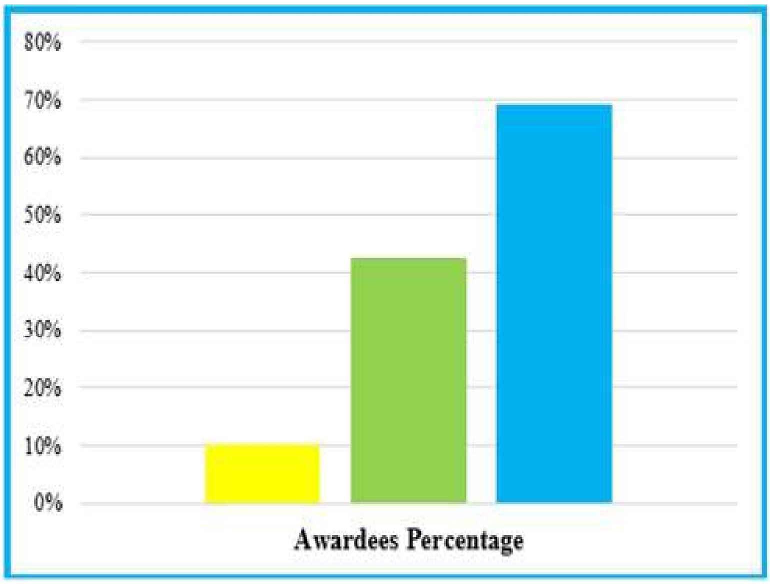

FIGURE 4.32: Awardees percentage in top-ranked authors.

to 42.64% when talking about the top 500. When considering top 1000 authors an enhancement of 69% is seen.

Figure 4.33 depicted the award winners occurrence in top 100, 500, and 1000 authors. When it comes to the top 100, the q2-index has the best performance as it gets 3.10% award winners. The r-index, h-index, hg-index and a-index all have equal performance: 1.60%. Regarding top 500, Hg-index retrieves 9.40% and performs the best. Q2-index and H-index have same performance: 7.9%. The g-index shows a performance of 6.30% and authors total publication performance was 6.20%. The q2-index performs the best in terms of 1000 authors, its performance is 12.5%. The second best is 11% of the hg-index, next is r-index, h-index, and g-index, which have equal 9.4% performance. 7.8% were retrieved by the author's total citations.

It has to be highlighted at this point that the results discussed above are calculated based on the full dataset of Mathematics. This means that most of the award winners have been retrieved by using all the parameters considered. The only difference is the efficiency of the parameters. However none of these parameters ("h-index, authors publication count, authors citation count, ar-index, a-index, q2-index, m-quotients, m-index, hg-index, and r-index")were able to retrieved even

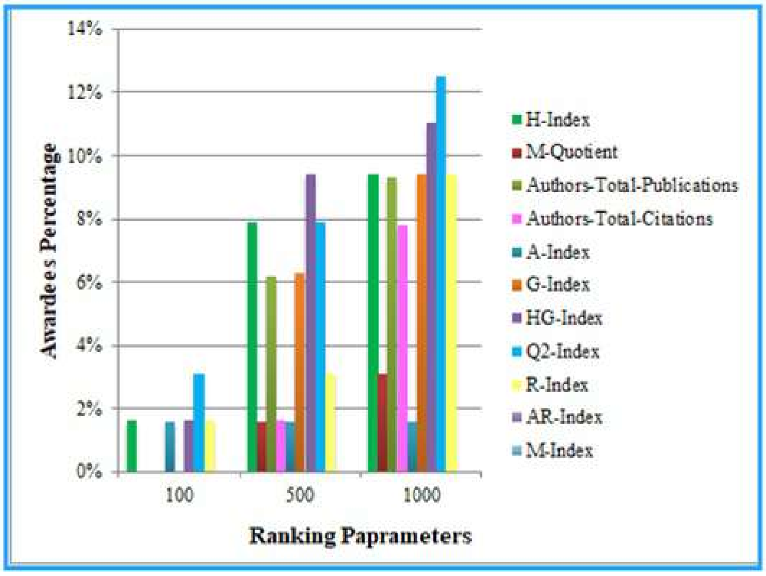

FIGURE 4.33: Awardees winners occurrence in top-ranked authors.

50 percent awardees at the top of the ranking list. Here, efficiency means how top-ranked authors have retrieved maximum awardees.

4.5 Ranking of Parameters for Classification

Our last research question is to rank the primitive, citation intensity and publication age based parameters for classification. Three classifiers Naive Bayes, k-Nearest Neighbour, and Support Vector Machine have been used to rank our ranking parameters. To evaluate the accuracy of a classifier we have calculated the Precision, Recall, and F-measure.

4.5.1 Naive Bayes Classifier

Naive Bayes is a parametric classification algorithm, i.e. the input values are supported over a supposed distribution. It assumes that the input values are nominal. This classification algorithm, as the name indicates, is a simple implementation of the Bayes theorem. It uses the training data to calculate probability for each class. It is assumed that the probabilities do not depend on each other. In technical terms, this is referred to as conditionally independent. This assumption is not realistic but it makes the process of calculating probabilities simple and easy. This supposition is untrue because the variables are expected to interact and be dependent. However, even with this unrealistic assumption, Naive Bayes works as a very effective classification algorithm.

Naive Bayes classification algorithm determines the posterior probability for each class and predicts the class having the highest probability. It can tackle both multi-class classification and binary classification problems. Naive Bayes is hailed as one of the most effective classification algorithms. Select the Naive Bayes Classification Algorithm:

- Select the "choose" button; you will see "Attribute Selected Classifier" under the "meta" group.
- Select "Naive Bayes".
- Select "Info Gain Attribute" as evaluator Click "OK" to close the configuration (as shown in Figure 4.34)
- After reviewing the configuration of algorithm, click on "OK" to close it.
- In order to run the selected algorithm, click the "Start" button. The algorithm will run on the dataset.

Figure 4.35 depicts the results of Naive Bayes classifier for the primitive, citations intensity, and publication age based ranking parameters for researcher's classification. It is evident for figure 4.35 that h-index is ranked in the first position, author's total citations at the second position and hg-index at the 3rd position according to Naive Bayes classifier.

4.5.2 k-nearest Neighbor Classifier

The k-nearest neighbor algorithm is a different type of algorithm that supports both regression and classification. It is abbreviated as k-NN. As the name suggests, the k-nearest neighbor algorithm operates by finding the k nearest training

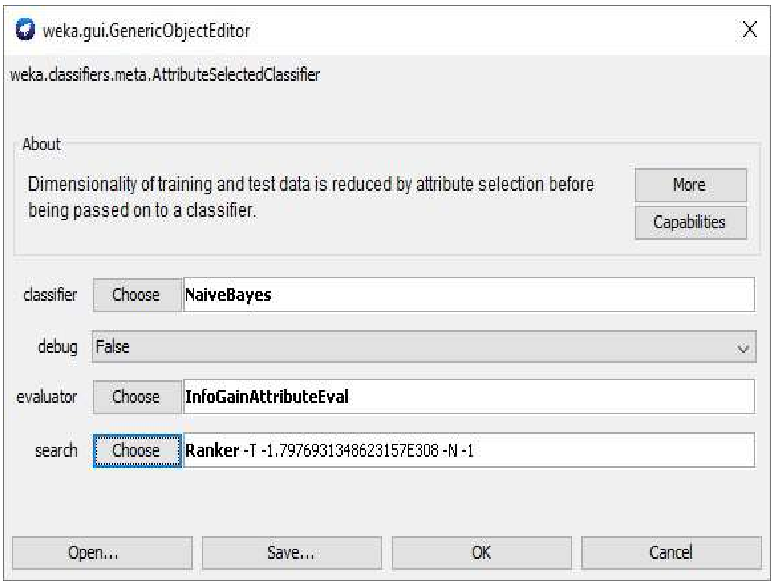

Figure 4.34: Configuration of Naive Bayes Classifier.

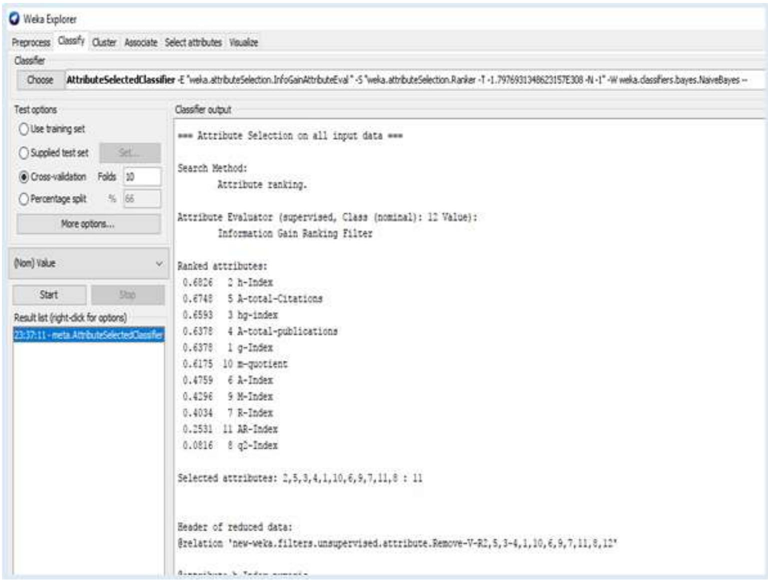

Figure 4.35: Ranking Using Naive Bayes Classifier.

patterns in the dataset in order to make a prediction. It does so by saving and querying the entire training dataset. This is a simple algorithm that uses no modal except the training dataset and the prediction is given by a single computation i.e. querying the entire dataset. K-nearest neighbors algorithm does not assume much about the problem except that the prediction has some degree of dependence on the distance between data instances such that the distance gives meaningful information about the prediction to be framed. Overall, this algorithm is shown to produce good results. When tackling classification problems, k-NN will scan the training data set to find the mode (most common class) of the k most similar instances. Follow the following steps to choose k-NN Algorithm:

- Select the "Choose" button and click on "IBk" under the "lazy" group.
- Select "Info Gain Attribute" as evaluator.
- The k parameter controls the size of the neighborhood, for example, if k is set to 1 then a single most similar training instance is used to draw predictions to a given new pattern for which prediction is requested. K parameter is commonly set to 3, 7, 11 or 21. For larger datasets, greater values of k may be used.
- Weka can suggest a suitable value of k parameter for a given dataset by using cross validation inside the algorithm. Cross validation happens when the cross validate parameter is set to True.
- Another important parameter is the distance measure used to calculate the distance between instances. The distance measure is configured in the Nearest Neighbor search algorithm which determines how the data is searched and stored. If any other measure is not selected, Euclidean distance will be used automatically to find the distance between instances. Euclidean distance is suitable for numerical data with the same scale.
- Click "OK" to close the configuration window.
- Finally, click the "Start" button to run the algorithm.

Figure 4.37 depicts the results of k-Nearest Neighbour classifier for the primitive, citations intensity, and publication age based ranking parameters for researcher's classification. It is evident from figure 4.37 that k-NN classifier has achieved same ranking of parameters as Naive Bayes.

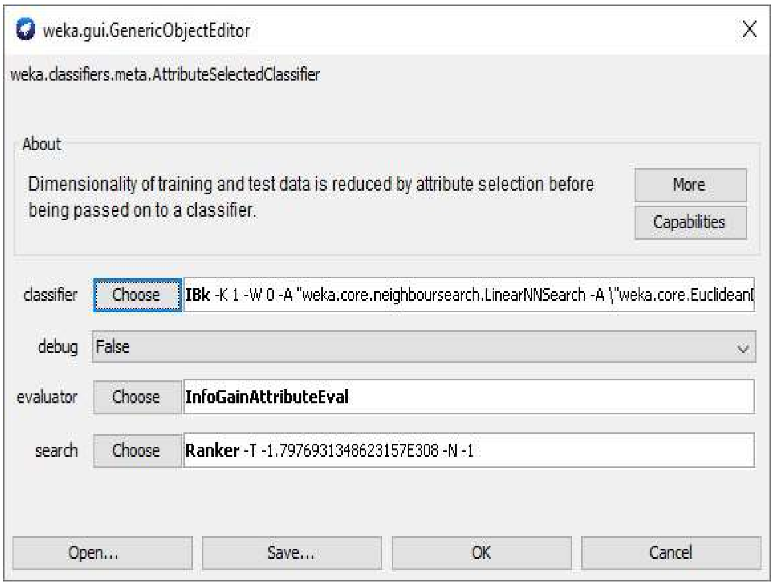

FIGURE 4.36: Configuration of k-NN Classifier.

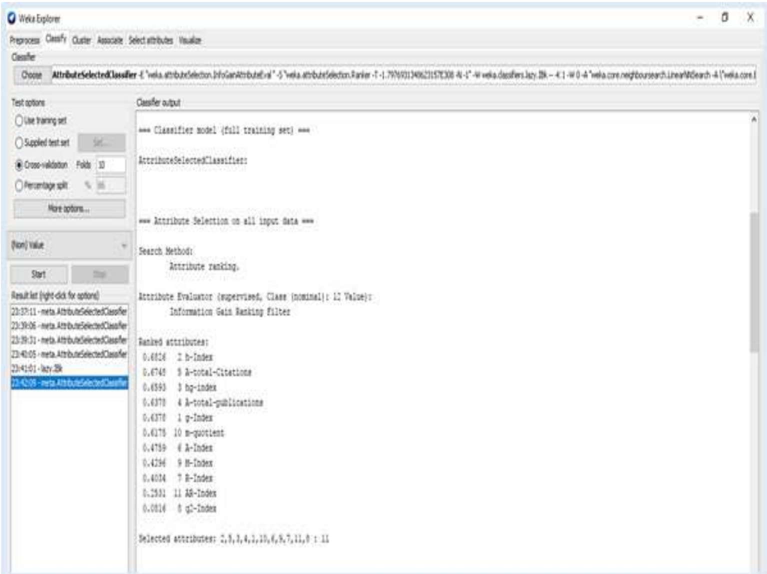

FIGURE 4.37: Ranking using k-NN.

4.5.3 Support Vector Machine

Support Vector Machines (SVM) is an algorithm that was developed specifically for binary classification. However, it has been modified over time to support regression problems and multi-class classification. SVM works on numeric input variables and is also equipped to convert nominal values to numeric values. The input data is used after it has been normalized. SVM works by separating the data into two groups using an optimization process. The process involves finding

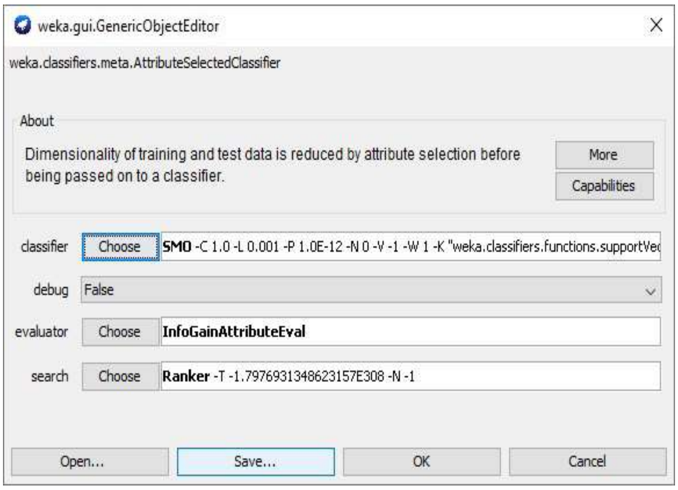

FIGURE 4.38: Configuration of SVM Classifer.

a line that best divides the data into 2 groups. This is done by considering only those data instances (support vectors) that are nearest to the line that can best divide the training dataset. In most cases, it is not possible to draw a single line to divide the data perfectly. To counter this issue, a margin is added around the line to relax the constraint. This misclassifies some data instances but gives a better overall result. Finally, it is very convenient to separate few datasets. A single straight line can be marked to perfectly separate the datasets fewer in number. In some cases, however, a straight line can not serve the purpose and a line with curves or polygonal regions needs to be made. This is done using Support Vector Machines that project the data into a higher dimensional space in order to make predictions and mark lines. Different kernels can be used to control the amount of flexibility in separation of classes and the projection of data.

The following steps explain the method to choose the SVM algorithm:

- Click the "Choose" button and select "SMO" under the "function" group.
- Select "Info Gain Attribute" as evaluator Click "OK" to close the configuration.

Figure 4.39 depicts the results of Support Vector Machine classifier for the primitive, citations intensity, and publication age based ranking parameters for researcher's classification. It is evident for figure 4.39 that SVM classifier has

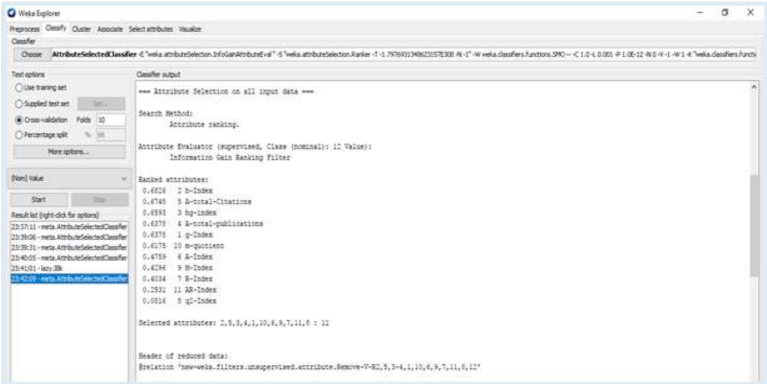

FIGURE 4.39: Ranking using SVM Classifier.

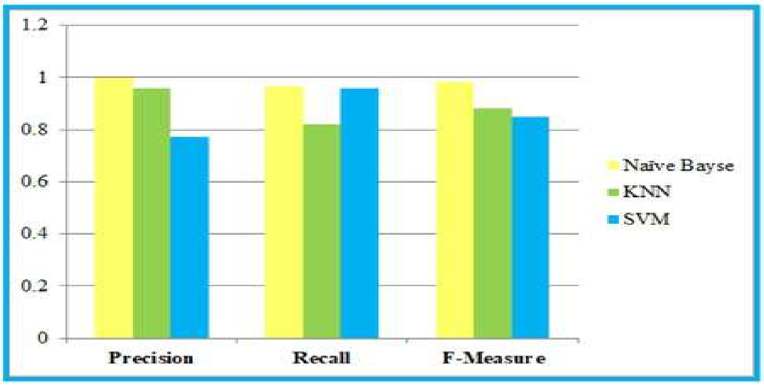

FIGURE 4.40: Precision, Recall and F-measure score of classifiers.

achieved same ranking of parameters as Naive Bayes and k-NN. It means that ranking parameters behaviors remains the same by applying the different classifier.

Figure 4.40 shows the Precision, F-Measure, and Recall score of Naive Bayes, k-NN and SVM classifiers. Naive Bayes classifier has achieved the precision of 0.99, Recall of 0.96, and F-measure of 0.98. k-NN classifier has achieved the precision of 0.96%, Recall of 0.82%, and F-measure of 0.88%. SVM classifier has achieved the precision of 0.77%, Recall of 0.96%, and F-measure of 0.85%. The best Precision, Recall, and F-measure scores have been achieved by Naive Bayes classifier.

Chapter 5

Conclusion and Future Work

5.1 Conclusion

The assessment of the contribution of researchers in the scientific community has got extreme importance, on behalf of its multifaceted benefits ever since. To acknowledge the contribution of any researcher in the scientific community, different parameters have been proposed such as an author's number of publications, citation count, etc. Based on such ranking parameters they are ranked by scientific societies to identify the most influential researchers. Likewise, giving promotions, and allocating funds to the deserver ones can be done suitably. In the research's perspective, it can be helpful for any conference or journal's organizers to select the most suitable reviewer for any research paper belonging to the specific domain. Ph.D. students can select a suitable supervisor appropriately. All this can be made possible by considering the author's rank in the scientific community. Regarding all this and many other benefits, it can be axiomatically said that the researcher rank depicts their contribution in the scientific society.

It is evident from the current-state-of-the-art literature review that there are two well-known ways and a combination of both, for the researcher's contribution evaluation purpose. The first method relies on the manual ranking, preferably performed by the domain relevant experts. Whereas, the second method is based on considering some research papers' based parameters like the publication age of the author, the citation counts of him and many others, in which we analyze the research work of an author. We have adopted the second method.

This research is meant to evaluate the role of the primitive (author's total publication, author's total citations, and h-index, publication age (m-quotient, and ar-index), and citation intensity (a-index, hg-index, g-index, q2-index, r-index, and m-index) based parameters. Moreover, this research also puts forward a more competent benchmark for testing; it is hailed to be the gold standard set which includes award winning international as well as national award winners societies of mathematics. We have also performed the classification using binary classifiers (k-NN, SVM, and Nave Bayes) and evaluation is done by finding the recall, f-measure, and precision.

Research question 1 was tackled by applying the Spearman Rank Correlation. The result of the calculation showed that strong correlation values overpower the weak ones among most of the primitive and citation intensity based parameters. The m-index and a-index have a negative correlation with h-index and author's total publications. The publication age based parameters mostly have a weak correlation with primitive and citation intensity based parameters. The ar-index has a negative correlation with the author's total publications and hg-index. The m-quotient has a negative correlation with g-index and r-index. The negative, weak and high correlation values indicate the level of similarity or dissimilarity among the lists

To answer the second research question, we found the occurrences of the award winners in the lists that were previously created. We compared the awardees with the top 10% of the ranked writers. The results indicate that no index succeeded in getting even 50% of that award winners. 31.2% awardees were brought by publication count, next is the 30.88% brought by h-index, and the 29.4% of g-index and hg-index. The benchmark dataset of this research contained 68 award winners from NASL, AMU, LMS, and IMU. AMS fetched 29 award winners (42.6%), IMU got 6 award winners (8.82%), LMS got 23 award winners (33.8%), and NASL got

8 awardees into the ranking list (11.76%). Only 10.29% awardees were brought into the top 100 by the parameters that were under study, the percentage changes to 42.64% when talking about the top 500. When considering top 1000 authors an enhancement of 69% is seen. When it comes to top 100, q2-index has the best performance. For the top 500, the best performance is of Hg-index. For the top 1000, q2-index has the best performance. To tackle the fourth research question, we found the differences between the parameters of various awarding societies. The most award winners fetched, who belong to the top 10 percent list are by AMS (41% by author's total publications), second is NASL at approximately 37.5%, and then the IMU with almost 33.33% and LMS with 21.37%. The results indicate that AMS fetched the most awardees to the top.

Three classifiers Nave Bayes, K-Nearest Neighbour, and Support Vector Machine have been used to rank our ranking parameters. To evaluate the accuracy of a classifier we have calculated the Precision, Recall, and F-measure. The h-index is ranked in the first position, author's total citations at the second position and hg-index at the 3rd position according to Nave Bayes classifier. Nave Bayes classifier has achieved the precision of 0.99%, Recall of 0.96%, and F-measure of 0.98%. The KNN classifier has achieved the same ranking of parameters as Nave Bayes and it has achieved the precision of 0.96%, Recall of 0.82%, and F-measure of 0.88%. The SVM also has achieved the same ranking as Nave Bayes and KNN. SVM classifier has achieved the precision of 0.77%, Recall of 0.96%, and F-measure of 0.85. The best Precision, Recall, and F-measure scores have been achieved by Nave Bayes classifier.

The ranking involving publication age based parameters, primitive parameters and citation intensity based parameters is quantitative as these parameters determine the position or importance of a scholar while giving only a slight indication of the quality of his or her scientific work. However, it is the quality of the scientific work that should be given utmost importance in scientific research ranking. The community does not benefit from the number of publications authored by a particular scientist or the number of citations that have been collected. What is truly important is the value that a particular scientific work carries in terms of advancement of new insights i.e. is the research of any good use, is it factually correct and error free, does it satisfy the stated needs and does it fulfill more general requirements of the society. The qualitative and quantitative metrics measure entirely different phenomenon. In the world of science, both types of scholars are required; those who can bring out a considerable number of publications and those who have the capability of running journals. Each of these options has its shortcomings and strengths which should be carefully evaluated. We do want to highlight a major disadvantage of quantitative rankings i.e. the scholarly work making important contributions may get ignored. The quantitative method of research ranking can crowd out important scientific contributions which clearly worsen the research quality instead of improving it. However, these findings are significant for both the researchers and decision makers. The purpose of ranking is to identify the scientific impact of the author and consider him for post-doctoral positions, tenure, and faculty. The decision makers will be able to make decisions regarding hiring researchers, giving promotions, awarding prizes, call the best authors as a speaker, and allocating funds.

5.2 Future Work

Many other parameters have been proposed by the scientific community. All of them need to assess on large and extensive datasets to expose their abilities. In the future, we hope to analyze other ranking parameters on comprehensive datasets of other domain than mathematics. One can create a homogenous dataset and the winners can be decided using a similar criterion. For example. 2 benchmarks may be constructed; one for junior authors and another for seniors and then compare the performance of all parameters

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Appendix A

Parameters	Formula definition
H-index	A scientist has index h, if h of his papers have at least h citations each and other papers have less than h citations each.
G-index	Given a set of scientist's paper arranged in the decreasing order of the citation count, the g-index is the single largest number such that at least g2 citations is received together by the top g articles.
Hg-index	$hg = \sqrt{h.g}$ If an authors h-index and the g-index are multiplied, and then the square root of the obtained value is taken, the resulting value is the hg-index of that author.
A-index	$A = \frac{1}{h}\sum_{j=1}^{h} C_i t_j$
R-index	$A = \sqrt{\sum_{j=1}^{h} C_i t_j}$
q^2-index	$q^2 = \sqrt{h.m}$
AR-index	$AR = \sqrt{\sum_{j=1}^{h} \frac{C_i tp}{ap}}$
M-Quotient	$MQ = \frac{H - index}{y}$
Citation	$C_{it}Count = \sum_{i=1}^{n} C_{it} P_i$
Publication	$P_{ub}Count = \sum_{j=1}^{n} P_i$
M-Index	Median of the citations of the papers that are a part of the Hirsch core.

Appendix B

Table 1: Delbert Ray Fulkerson Prize

First name	Last name	Receiving Year
John	Friedlander	2017

Table 2: Bcher Memorial Prize

First name	Last name	Receiving Year
Andrs	Vasy	2017

Table 3: Cole Prize in algebra

First name	Last name	Receiving Year
Robert	Guralnick	2018
Peter	Scholze	2015

Table 4: Cole Prize in Number Theory

First name	Last name	Receiving Year
Henri	Darmon	2017

Table 5: Naylor prize and lectureship in applied mathematics

First name	**Last name**	**Receiving Year**
John	King (GP)	2017
S.J.	Chapman (S)	2015

Table 6: Delbert Ray Fulkerson Prize

First name	**Last name**	**Receiving Year**
Robert	Morris (RJ)	2018
Yoshiharu	Kohayakawa	2018
Simon	Griffiths	2018
Peter	Allen (MP)	2018
Julia	Bttcher	2018
Thomas	Rothvoss	2018
Francisco Santos	Leal	2015

Table 7: Leroy P. Steele Prize for Lifetime Achievement

First name	**Last name**	**Receiving Year**
Jean	Bourgain	2018
James G.	Arthur (MA)	2017
Barry	Simon	2016
Victor	Kac	2015

TABLE 8: Leroy P. Steele Prize for Mathematical Exposition

First name	**Last name**	**Receiving Year**
Martin	Aigner	2018
Gnter M.	Ziegler	2018
Dusa	McDuff	2017
Dietmar	Salamon	2017
David A.	Cox	2016
John	Little	2016
Donal	O'Shea	2016
Robert	Lazarsfeld	2015

TABLE 9: Leroy P. Steele Prize for Seminal Contribution to Research

First name	**Last name**	**Receiving Year**
Sergey	Formin	2018
Andrei	Zelevinsky	(AV) 2018
Leon	Simon (LK)	2017
Andrew	Majda (AJ)	2016
Rostislav	Grigorchuk (RI)	2015

Table 10: Levi L. Conant Prize

First name	**Last name**	**Receiving Year**
Henry	Cohn	2018
David H.	Bailey	2017
Jonathan	Borwein (D)	2017
Andrew	Mattingly (AC)	2017
Glenn	Wightwick	2017
Daniel	Rothman (DH)	2016
Jeffrey	Lagarias (JC)	2015
Zong	Chuanming	2015

Table 11: Oswald Veblen Prize in Geometry

First name	**Last name**	**Receiving Year**
Fernanda	Cod	Marques 2016
Andr	Neves	2016

Table 12: Chern Medal Prize

First name	**Last name**	**Receiving Year**
Masaki	Kashiwara	2018

Table 13: b. Fields Medal

First name	**Last name**	**Receiving Year**
Caucher	Birkar	2018
Alessio	Figalli	2018
Peter	Scholze	2018
Akshay	Venkatesh	2018

Table 14: Gauss Prize

First name	Last name	Receiving Year
David L.	Donoho	2018

Table 15: Leelavati Prize

First name	Last name	Receiving Year
Ali	Nesin	2018

Table 16: Rolf Nevanlinna Prize

First name	Last name	Receiving Year
Constantinos	Daskalakis	2018

Table 17: Berwick Prize

First name	Last name	Receiving Year
Kevin	Costello (KP)	2017
Pierre	Emmanuel Caprace	2015
Nicolas	Monod	2015

Table 18: Frohlich Prize

First name	Last name	Receiving Year
Francesco	Mezzadri	2018
Dominic	Joyce	2016

Appendix C

1. Abstract Harmonic Analysis

1.1. Amenable groups

1.2. Lp-spaces

2. Algebraic Geometry

2.1. Affine fibrations

2.2. Elliptic surfaces

2.3. Picard group

2.4. Riemann-roch theorems

2.5. Rigid analyticgeometry

3. Algebraic Topology

3.1. Elliptic cohomology

3.2. Fiber spaces

3.3. H-spaces and duals

3.4. J-morphism

3.5. K-theory

3.6. Loop spaces

3.7. Orbifoldcohomology

4. Approximations and Expansions

4.1. Chebyshev systems

4.2. Pade approximation

5. Associative Rings and Algebras

5.1. Hopf algebra

5.2. Lattices over orders

5.3. Nil and nilpotent radicals

5.4. Quasi-frobenius rings

6. Calculus of Variations and Optimal Control Optimization

6.1. Differential games

6.2. Duality theory

6.3. Frechet and gateaux differentiability

6.4. Hamilton-Jacobi theories

6.5. Inverse problems

6.6. Minimax problems

7. Category Theory

7.1. Adjointfunctors

7.2. Epimorphisms, monomorphisms

7.3. Functor categories

7.4. Monoidal categories

8. Combinatorics

8.1. Generalized remsey

8.2. Infinite Graphs

8.3. Matroids, geometric lattices

8.4. Matroids, geometric

8.5. Polyominoes

8.6. Q-calculus

9. Commutative Algebra

9.1. Cluster algebras

9.2. Cohen-macaulay modules

9.3. Formal power series rings

9.4. Morphisms

9.5. Seminormal rings

9.6. Witt Vectors

10. Convex and Discrete Geometry

10.1. Convex sets without dimension restrictions

10.2. Helly-type theorems

10.3. Isoperimetric problems

10.4. Lattice polytopes

10.5. Matroids

10.6. Spherical and hyberbolic convexity

11. Difference and Functional Equations

11.1. Stochastic difference equations

12. Differential Geometry

12.1. Classical differential geometry

12.2. Differential line geometry

12.3. Euclidean space

12.4. G structures

12.5. Kinematics

12.6. Projective connections

13. Dynamical Systems and Ergodic Theory

13.1. Cellular automata

13.2. Chaotic dynamics

13.3. Ergodic theorems

13.4. Homoclinic and heteroclinic orbits

13.5. Index Theory

13.6. Lattice dynamics

13.7. Monotone flows

13.8. Morse-smale systems

13.9. Nonholonomic dynamical systems

13.10. Notions of recurrence

13.11. Partially hyperbolic systems

13.12. Soliton theory

13.13. Symbolic dynamics

14. Field Theory and Polynomials

14.1. Hilbertian fields

14.2. Homological methods

14.3. Nonstandard arithmetic

14.4. P-adic differential equations

14.5. Skew fields

14.6. Topological semifields

15. Functional Analysis

15.1. Barelled spaces, bornological spaces

15.2. Locally convex frechet spaces

15.3. Saks spaces

15.4. Sequence spaces

15.5. Sobolev spaces

16. Functions of a Complex Variable

16.1. Bergman spaces, fock spaces

16.2. Boundary value problems

16.3. Hardy spaces

16.4. Klein surfaces

16.5. Kleinian groups

16.6. Meromorphic functions

16.7. Quasiconformal mappings

17. General Algebraic Systems

17.1. Automorphisms, endomorphisms

17.2. Infinitary algebras

18. General Topology

18.1. Fuzzy topology

18.2. Hyperspaces

18.3. Moore spaces

18.4. P-minimal and P-closed spaces

18.5. Quotient spaces

18.6. Spectra

18.7. Syntopogenous structures

19. Geometry

19.1. Affine analytic geometry

19.2. Configuration theorems

19.3. Discrete geometry

19.4. Laguerre geometry

19.5. Linear incidence geometry

19.6. Metric geometry

19.7. Mobius geometry

19.8. Polar geometry

19.9. Ring geometry

19.10. Steiner systems

20. Global Analysis on Manifolds

20.1. Bifurcation theory

20.2. Critical metrics

20.3. De Rham theory

20.4. Hodge theory

20.5. Pfaffian systems

21. Graph Theory

21.1. Hypergraphs

21.2. Ramsey theory

21.3. Random Graphs

22. Group Theory and Generalizations

22.1. Braid groups, Artin groups

22.2. Conjugacy classes

22.3. Fuzzy groups

22.4. Nilpotent groups

22.5. Orthodox semigroups

23. Harmonic Analysis on Euclidean Spaces

23.1. Conjugate functions

23.2. Convolution factorization

23.3. Fourier series

23.4. Harmonic analysis

24. Integral Equations

24.1. Eigen value problems

24.2. Fredholm integral equations

24.3. Integro-ordinary differential equations

24.4. Integro-partial differential equations

24.5. Volterra integral equations

25. Integral Transforms Operational Calculus

25.1. Laplace transform

25.2. Randon transform

26. K-theory 26.1. Steinberg groups and K2

26.2. Whitehead groups and K1

27. Linear and Multi Linear Algebra; Matrix Theory

27.1. Clifford algebras, spinors

27.2. Fuzzy Matrices

27.3. Hermitian, skew-hermitian

28. Manifolds and Cell Complexes

28.1. Cobordism and Concordance

28.2. Diffeomorphisms

28.3. Differential topology

28.4. Flatness and tameness

28.5. Isotopy and pseudo-isotopy

28.6. PL-topology

29. Mathematical Logic and Foundations

29.1. Algebraic logic

29.2. Axiom of choice and related propositions

29.3. Computability and recursion theory

29.4. Fuzzy set theory

29.5. Godel numberings and issues of incompleteness

29.6. Lukasiewicz and post algebras

30. Measure and Integration

30.1. Fractals

30.2. Fuzzy measure theory

31. Non associative Rings and Algebras

31.1. Color lie Algebra

31.2. Graded lie algebra

31.3. Leibniz algebra

31.4. Modular lie algebra

31.5. Vertex operators

32. Number Theory

32.1. Automorphism groups of lattices

32.2. Bell and Stirling numbers

32.3. Bernoulli and Euler number and polynomials

32.4. Bilinear and hermitian forms

32.5. Binomial coefficients; factorials; q-identities

32.6. Dedekind eta functions dedeking sums

32.7. Diophantine inequalities

32.8. Fibonacci and Lucas number and polynomials and generalization

32.9. Galois cohomology of linear algebraic groups

32.10. Galois Theory

32.11. Hecke-petersson operators

32.12. Jacobi forms

32.3. K-theory of quadratic and Hermitian forms

32.14. Non convex bodies

32.15. Nonholomorphic modular forms

32.16. The frobenius problem

32.17. Thue-Mahler equations

32.18. Weil representation

33. Numerical

33.1. Monte carlo methods

33.2. Numerical differentiation

33.3. Numerical integration

33.4. Numerical Linear Algebra

33.5. Smoothing, curve fitting

33.6. Splines

33.7. Stiff equations

34. Operator Theory

34.1. C-semigroups

34.2. Difference operators

34.3. Functional calculus

34.4. Hermitian and normal operators

34.5. 111-posed problems

34.6. Jacobi operators

34.7. Kernel operators

34.8. Markov semigroups

34.9. Perturbation theory

34.10. Random operators

34.11. Riesz operators

34.12. Spectral operators

35. Order, Lattices, Ordered Algebraic Structures

35.1. Fuzzy lattices

35.2. Modular Lattices, Complemented Lattices

35.3. Noether Lattices

35.4. Stein manifolds

36. Ordinary Differential Equations

36.1. Fuzzy differential equations

36.2. Lattice differential equations

36.3 Spectral theory

36.4. Wey1 theory

37. Partial Differential Equations

37.1. Boltzmann equations

37.2. Close-to-elliptic equations and systems

37.3. Hamilton-jacobi equations

37.4. Nonlinear elliptic equations

37.5. Overdetermined systems

37.6. Schrodinger operator

37.7. Singular elliptic equations

37.8. Soliton solutions

37.9. Strong solutions

37.10. Weak solutions

38. Potential Theory

38.1. Axiomatic potential theory

38.2. Dirichlet spaces

39. Probability Theory

39.1 Combinatorial probability

39.2. Fuzzy probability

39.3. Geometric probability

39.4. Limit theorems

39.5. Markov processes

39.6. Stochastic analysis

39.7. Stochastic processes

40. Real Functions

40.1. Fuzzy real analysis

40.2. Lipschitz classes

40.3. Quasi-analytic functions

41. Sequences Series Summability

41.1. Lacunary inversion theorems

41.2. Tauberian constants

42. Several Complex Variables and Analytic Spaces

42.1. Automorphic forms

42.2. Geometric convexity

42.3. Holomorphic convexity

42.4. Kahler manifolds

42.5. Lelong numbers

42.6. Milnor fibration

42.7. Pseudoholomorphic

42.8. Semi-Analytical sets

42.9. Twistor theory, double fibrations

43. Special Functions

43.1. Airy functions

44. Statistics

44.1. Decision theory

44.2. Distribution theory

44.3. Linear regression

44.4. Multivariate analysis

44.5. Parametric inference

45. Topological Groups, Lie Groups

45.1. Ergodic theory

45.2 Infinite-dimensional lie groups