Research Article

Patterns of Research Productivity in the Virtual Worlds Literature: A Bibliometric Approach

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Abstract

Since the beginning of the 21st century, the internet has provided a much more dynamic platform, becoming more visual and allowing users to interact with each other in communities and share information in real time. The new Internet is a social media, and online communities are taking on a new dimension, quite literally, in the form of immersive 3D virtual worlds, such as such as Active Worlds, OSGrid, and Second Life. Surprisingly, 80% of active internet users have a registered account in virtual worlds which are playing an increasingly important role in the lives of many adults, teens, and children. Indeed, virtual worlds are believed to have implications that go beyond how we play, to also include how we buy, work, and learn. In recent years there has been increased behavioral research in virtual reality and virtual worlds. As a result, the subject of virtual world has become a major research area in recent years. To shed light on virtual worlds' trends, and contributions, a historical review and Bibliometric analysis are included in this research. The Bibliometric analytical technique was used to examine this topic in SSCI journals from 1991 through 2011. Also, the study investigated whether author productivity conformed to Lotka's Law, to understand author distributions within the field of virtual worlds and to elucidate the distributions of the core authors.

Keywords*:* Bibliometrics, Lotka's law, virtual worlds

1. Introduction

Since the beginning of the 21st century, the Internet has provided a much more dynamic platform, becoming more visual and allowing users to interact with each other in communities and share information in real time. The new Internet is a social medium, and online communities are taking on a new dimension, quite literally, in the form of immersive three-dimensional (3D) virtual worlds. A virtual world, sometimes also called digital worlds or Metavarse, is a computer-based simulated environment, usually modeled after the real world, accessed through an online interface, and inhabited by users in the form of avatars- a representative of a real person in virtual world

(Kaplan and Haenlein, 2009).

The high growth of various virtual worlds globally that has occurred in recent years has prompted a number of Fortune 2,000 companies to either enter the virtual space, or at least monitor the development and potential of avatar-based business, such as Apple, IBM, Nike, GM and Disney, have begun to extend their businesses to virtual worlds. Even the American Cancer Society has used Second Life to promote its annual event. The use of virtual worlds is beginning to grow rapidly far beyond people's expectations (Hua and Haughton, 2009).

The current virtual worlds have their roots in different text-based environments, for example, discussion forums and multi-user dungeons (MUDs), which emerged as early as in the late 1970s and gained wide success in the **1990s** when Internet became commonplace. One of the main advantages of virtual worlds is overcoming the limitations related to geographical distances (the need to commute). During the last few years, 3D virtual worlds have finally gained global popularity. The most advanced environments provide their users with detailed 3D graphics, animation, different communication methods including voice communication, features for personalization and building new objects, and a massive number of places and objects created by others already available (Partala, 2011).

Virtual worlds include everything from massive multiplayer online role-playing games (MMORPGs), such as World of Warcraft (WoW), to virtual realities such as Second Life. The business world has assumed that virtual worlds can be leveraged to provide access to consumers and consumer data (Spaulding, 2010). In recognition of the growing importance of avatars as 3D representations of people and their alter egos in virtual worlds, Google has a project underway to develop "universal" avatars that can move between virtual worlds. Some authors even suggest that the 3D Internet will become as important to companies in five years as the Web is now (Messinger, Stroulia, and Lyons, 2008).

In the last decade, the digital revolution affected various social-economic areas. Among the many venues of research, nowadays the attention is gathered by two distinct, yet interrelated, innovative threads: the so-called Web 2.0 and the rise of virtual worlds. As both phenomena are recent and highly dynamic they have not been clearly understood and explained yet. Virtual worlds have captured the interest of many scholars and practitioners, in particular because the entrance of many real world companies, attracted by the potentialities of virtual worlds, has been interpreted as the signal for the discovery of new web-based business models, in the same vein the boom of Internet did in the past (Cagnina and Poian, 2009).

In this paper, we are going to direct our efforts on the rise of virtual worlds, in order to understand their features. Therefore, we explored virtual world's research trends and forecasts by means of bibliometric from 1991 through 2011 to elucidate the virtual worlds' trends in adopting enterprises, contributions that virtual worlds are making, and forecasts for virtual worlds' growth.

2. Background

2.1 What is "virtual worlds"?

Virtual Worlds are virtual places that enables users to communicate, cooperate, and collaborate, as in the real world (Hindmarsh, Heath, and Fraser 2006), which are considered a sub-set of the vaster field of Web 2.0 themes

(Cagnina and Poian, 2009). Virtual worlds are understood as immersive, 3D, multimedia, multi-person simulation environments, where each participant adopts an alter ego and interacts with the world in real time. World activity persists even if a player is off-line (Wagner and Ip, 2009).

According to Harrison, Haruvy, and Rutström (2011), the virtual worlds simply mean something that is like something else, but without some of the properties of that which it is like. Although that sounds vague, some examples illustrate why one would want a general definition. In the context of computers, the word virtual just means computer simulated. Thus, a virtual environment implies that something inherent to the physical environment in which a user is communicating, socializing or gathering information is computer generated or mediated. Virtual worlds are perhaps the most extensive form of virtual environments, involving visual simulations that allow interactions between people in real time.

Eisenbeiss et al. (2012) define virtual worlds as an unstructured social and technological environment that possesses three central characteristics: (1) It is embedded in a three-dimensional, visually sophisticated digital space; (2) it comprises an aggregation of people who are graphically represented by avatars, and movements of these avatars within the digital space are rendered simultaneously to all other constituents in the virtual vicinity in a three-dimensional visualization that enables real-time interaction; and (3) users of the virtual worlds engage in different exchange processes, whether social (mutual dissemination of thoughts and opinions), material (trading virtual material objects), or monetary (transfer of virtual currency). Every constituent engages in some but not necessarily all exchange processes. This definition distinguishes virtual worlds from related virtual venues, such as multiplayer online games or virtual communities.

2.2 What are the features of virtual worlds?

Generally, virtual worlds is “an electronic environment that visually mimics complex physical spaces, where people can interact with each other and with virtual objects, and where people are represented by animated characters” (Bainbridge, 2007). Open or unstructured virtual worlds represent a blending of the elements of immersive 3D gaming environments, developed in the gaming industry over the last 25 years, together with elements of online social networking. This conclusion can be seen by tracing the development of electronic gaming since the 1970s, including (a) arcade games, (b) console games, (c) LAN games with more players, (d) games with Internet connectivity, (e) unstructured games with many players, (f) massive games with user-generated content, and (g) immersive 3D worlds with designer-provided objectives. Open virtual worlds combine the last three items with elements of web-based social networking. Open virtual worlds, thus, consist of massively multiplayer gaming platforms with unstructured objectives, user-generated content, immersive 3D virtual reality shared environments, and social networking elements used between people through their avatars (Messinger, Stroulia, and Lyons, 2008).

Cagnina and Poian (2009) outline that the founding characteristics of virtual worlds are:

1. Interactivity: it exists on one computer but can be accessed remotely (i.e. by an Internet connection) and simultaneously by a large number of people, with the command inputs of one person affecting the command results of other people.
2. Physicality: people access the program through an interface that simulates a first person physical environment on their computer screen; the environment is generally ruled by the natural laws of Earth and is characterized by scarcity of resources.

3. Persistence: the program continues to run whether anyone is using it or not; it remembers the location of people and things, as well as the ownership of objects.

Furthermore, there are three-dimensional spaces perceived by users in virtual world, which provide them with an interactive experience with virtual objects, as well as with other virtual worlds' denizens (Saunders et al., 2011):

1. Perceptual space is defined as "that can be seen or sensed at one place and at one time," which is created by manipulating objects, interacting socially, and otherwise experiencing the virtual world through the senses.
2. Cognitive space is the large-scale space beyond the sensory horizon about which information must be mentally organized, stored, and recalled in which users have experienced the virtual world through their senses.
3. Universal space is defined as an"image of the environment" or a relatively stable system based on experiences with things and others.

In comparison to other social media, virtual worlds have three characteristics that differentiate them from other applications. First, virtual worlds allow users to interact with others in real time. Second, virtual worlds allow users to create fully customized virtual self-presentations in the form of avatars. Finally, while content communities, blogs, and collaborative sites are two-dimensional (i.e., focused on content sharing), avatars within virtual worlds have the possibility of exploring their virtual environment in three dimensions (Kaplan and Haenlein, 2009).

2.3 What are the elements of typology of virtual worlds?

Messinger, Stroulia, and Lyons (2008) proposed a five-Ps typology of virtual worlds, which could be used for research and application on society, education, and business:

1. Purpose (Content of Interaction): whether a game has a strategic, tactical, or thematic appeal, (b) whether the network is themed (has a specific purpose) or is open, and (c) for virtual worlds, whether there is an age focus, a content focus, or it is open.
2. Place (Location of Interaction): whether players are collocated or geographically dispersed.
3. Platform (Design of Interaction): focusing on synchronous communication, asynchronous communication, or both, or various gaming platforms.
4. Population (Pattern of Interaction): focusing on the size of the group, the types of social ties, and the characteristics of the target user market.
5. Profit Model (Return on Interaction): whether the virtual world supports (1) a single purchase price or registration fee (i.e., fixed fee); (2) fee per use (i.e., variable fee); (3) subscription based (and on what basis subscriptions are made); (4) advertising-based; (5) pay-as-you-go extras (virtual assets including clothing, land, and software); and (6) sale of ancillary products, such as real stuffed animals and accessories, which are accompanied by passwords for accounts in virtual worlds where virtual versions of the products enable combined real and virtual play.

2.4 What are the studies of virtual worlds?

The literatures of virtual worlds can be classified as the following categories:

1. Studies that investigate the link between individuals and their avatars in VWs as well as the impact of VWs on virtual identity building (e.g., Bélisle and Bodur, 2010; Parmentier and Rolland, 2009);
2. Studies that analyze the experiences in the VW and consumer purchase behavior in the real world (e.g., Animesh et al., 2011, Gabisch, 2010; Haenlein and Kaplan 2009).
3. Studies that investigate what actually motivates people to join and participate in a VW. (e.g., Eisenbeiss et al., 2012; Partala, 2011).
4. Studies that examine the determinants of virtual worlds' user adoption (e.g., Fetscherin and Lattemann, 2008; Hua and Haughton, 2009; Shin and Kim, 2008).

3. Methodology

All documents used in this study were accessed from the database of the Social Science Citation Index (SSCI), obtained by subscription from the ISI, Web of Science, Philadelphia, PA, USA. In this study, we only discuss the papers published in the period beginning 1991 because there were less data regarding virtual worlds prior to that year.

To shed light on virtual worlds' trends and contributions, a bibliometric analysis was conducted in this research. For the bibliometric analysis, the SSCI was systematically searched for virtual worlds-related materials published from 1991 through 2011. Selected documents included ‘‘virtual world*’’ in the topic. Analyzed parameters included authorship, patterns of international collaboration, journal, language, document type, research address, number of times cited, and reprint author's address.

The analyses included whether the growth and distribution of literature and author productivity are in compliance with Lotka's Law, with the purpose of understanding the growth and types of virtual worlds literature as well as the major research institutions.

Lotka's law' describes the frequency of publication by authors in a given subject field, it stated that "... the number (of authors) making n contributions is about $1/ n^2$ of those making one: and the proportion of all contributors, that make a single contribution, is about 60 percent." This means that out of all the authors in a given subject, about 60% publish only one article, 15% ($1/2^2$ times .60) publish two articles, 7% ($1/3^2$ times .60) publish three articles, and so on. According to Lotka, only 6% authors in a subject field produce more than ten articles. Lotka's law is often called inverse square law indicating that there is an inverse relation between the number of publications and the number of authors producing these publications (Zabed Ahmed and Anisur Rahman, 2009).

4. Results and Discussion

4.1. Publication statistics

The key word ‘‘virtual world*’’ was used to search SSCI entries from 1991 to 2011 (updated December 31, 2011). The virtual worlds SSCI article distribution status was used for trend analysis. Table 1 indicated that all 1,731 papers found in the search were analyzed.

Table 1. Distribution of virtual worlds published in each year between 1991 and 2011

Publication Years	Record Count	%
2011	233	13.46
2010	251	14.5
2009	216	12.478
2008	155	8.954
2007	102	5.893
2006	82	4.737
2005	68	3.928
2004	62	3.582
2003	75	4.333
2002	72	4.159
2001	90	5.199
2000	81	4.679
1999	60	3.466
1998	55	3.177
1997	46	2.657
1996	44	2.542
1995	18	1.04
1994	8	0.462
1993	9	0.52
1992	3	0.173
1991	1	0.058

4.2. Distribution by country/territory and institution name

Table 2 shows the distribution of publications by country and territory. The US, England, Germany, Canada, Australia, Italy, Netherlands, Spain, China, and Taiwan were the top ten countries publishing virtual worlds literatures. Listing publications by institution name, Table 2 also shows that the University of Illinois, University of Central Florida, Indiana University, University of South California, and University of Washington are the top five virtual worlds research institutions.

Table 2. Distribution by country/territory and institution name

Country/Territory	Record Count	%	Institution	Record Count	%
USA	759	43.847	**UNIV ILLINOIS**	24	1.386
ENGLAND	215	12.421	**UNIV CENT FLORIDA**	23	1.329
GERMANY	91	5.257	**INDIANA UNIV**	21	1.213
CANADA	88	5.084	**UNIV SO CALIF**	20	1.155
AUSTRALIA	61	3.524	**UNIV WASHINGTON**	20	1.155
ITALY	61	3.524	**UNIV WISCONSIN**	18	1.04
NETHERLANDS	56	3.235	**IST AUXOL ITALIANO**	17	0.982
SPAIN	54	3.12	**HARVARD UNIV**	16	0.924
PEOPLES R CHINA	40	2.311	**MIT**	15	0.867
TAIWAN	35	2.022	**STANFORD UNIV**	15	0.867
FRANCE	34	1.964	**UNIV CALIF LOS ANGELES**	15	0.867
SWITZERLAND	33	1.906	**UNIV CALIF SANTA BARBARA**	13	0.751
SOUTH KOREA	29	1.675	**UNIV CATTOLICA SACRO CUORE**	13	0.751
SWEDEN	26	1.502	**UNIV JAUME 1**	13	0.751
JAPAN	24	1.386	**UNIV MINNESOTA**	13	0.751
WALES	24	1.386	**CITY UNIV HONG KONG**	11	0.635

Country/Territory	Record Count	%	Institution	Record Count	%
ISRAEL	23	1.329	MIAMI UNIV	11	0.635
SCOTLAND	23	1.329	OPEN UNIV	11	0.635
FINLAND	20	1.155	UCL	11	0.635
AUSTRIA	16	0.924	UNIV NOTTINGHAM	11	0.635
BRAZIL	14	0.809	UNIV PENN	11	0.635
NEW ZEALAND	14	0.809	UNIV TORONTO	11	0.635

4.3. Distribution by publication year, document type and language

Table 3 displays virtual worlds-related publications by year, document type, and language. Figure 1 shows the number and percentage of annual publications output. In the SSCI, articles comprised the majority of published virtual worlds document types (Table 3). As for distribution by language, we see from Table 3 that the majority language of virtual worlds research is done in English. One interesting finding is that the publication had a drop in 2002 and 2004 respectively, and there has been a re-increase in virtual worlds research since 2005; it is clear that virtual world is becoming ever more important.

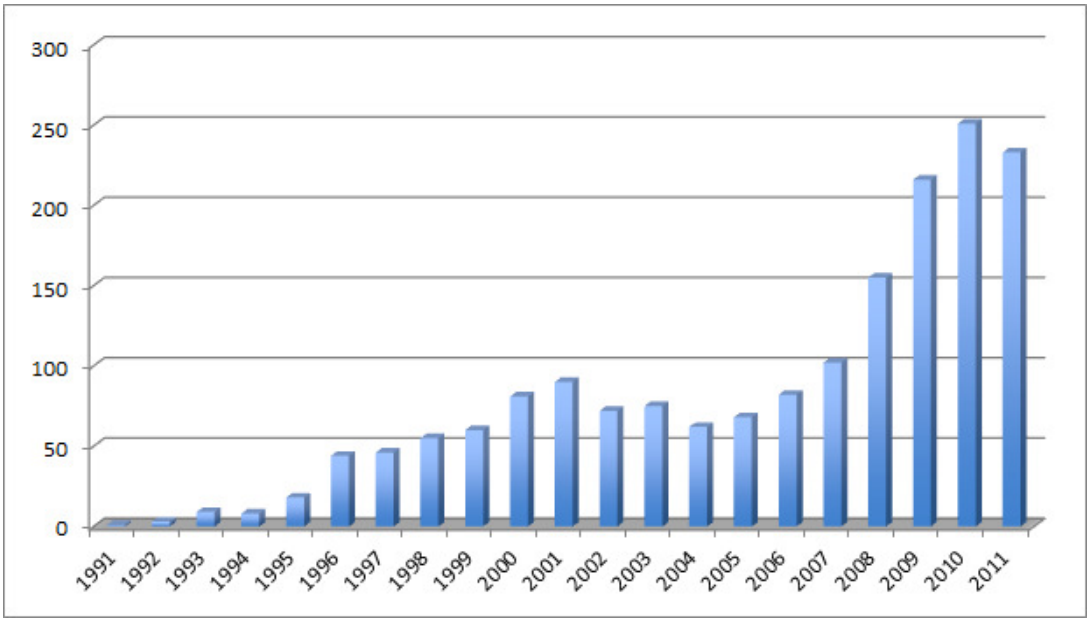

Figure 1. The growth trend of virtual worlds literature

Table 3. Distribution by publication year, document type and language

Pub. Year	Record No.	%	Document Type	Record No.	%	Language	Record No.	%
1991	1	0.058	ARTICLE	1504	86.886	ENGLISH	1649	95.263
1992	3	0.173	PROCEEDINGS PAPER	117	6.759	GERMAN	28	1.618
1993	9	0.52	REVIEW	74	4.275	SPANISH	15	0.867
1994	8	0.462	BOOK REVIEW	66	3.813	FRENCH	10	0.578
1995	18	1.04	EDITORIAL MATERIAL	54	3.12	PORTUGUESE	6	0.347
1996	44	2.542	MEETING	23	1.329	CZECH	5	0.289

Pub. Year	Record No.	%	Document Type	Record No.	%	Language	Record No.	%
			ABSTRACT					
1997	46	2.657	**NEWS ITEM**	5	0.289	**RUSSIAN**	5	0.289
1998	55	3.177	**CORRECTION**	3	0.173	**SLOVENIAN**	3	0.173
1999	60	3.466	**NOTE**	2	0.116	**ITALIAN**	2	0.116
2000	81	4.679				**RUMANIAN**	2	0.116
2001	90	5.199				**CROATIAN**	1	0.058
2002	72	4.159				**JAPANESE**	1	0.058
2003	75	4.333				**NORWEGIAN**	1	0.058
2004	62	3.582				**SLOVAK**	1	0.058
2005	68	3.928				**SWEDISH**	1	0.058
2006	82	4.737				**UNSPECIFIED**	1	0.058
2007	102	5.893						
2008	155	8.954						
2009	216	12.478						
2010	251	14.5						
2011	233	13.46						

4.4. Distribution by source title

Table 4 shows that ‘‘Cyberpsychology Behavior”, “Computer Education,’’ ‘‘Presence Teleoperators and Virtual Environments,’’ “Computer in Human Behaviors,” and “British Journal of Education Technology,” are the journals with the most publications on virtual worlds. In total, there are 768 journals had published 1,731 virtual worlds literatures. Through the 768 journals, 544 journals only published one literature among those journals.

Table 4. Distribution by source title

Source Titles	Record Count	%
CYBERPSYCHOLOGY BEHAVIOR	77	4.448
COMPUTERS EDUCATION	39	2.253
PRESENCE TELEOPERATORS AND VIRTUAL ENVIRONMENTS	36	2.08
COMPUTERS IN HUMAN BEHAVIOR	29	1.675
BRITISH JOURNAL OF EDUCATIONAL TECHNOLOGY	26	1.502
INTERNATIONAL JOURNAL OF HUMAN COMPUTER STUDIES	23	1.329
ELECTRONIC LIBRARY	16	0.924
CYBERPSYCHOLOGY BEHAVIOR AND SOCIAL NETWORKING	15	0.867
GAMES AND CULTURE	15	0.867
NEW MEDIA SOCIETY	15	0.867
LIBRARY JOURNAL	14	0.809
NURSE EDUCATOR	14	0.809
ERGONOMICS	12	0.693
INTERNATIONAL JOURNAL OF HUMAN COMPUTER INTERACTION	12	0.693
MIS QUARTERLY	12	0.693
BEHAVIOUR INFORMATION TECHNOLOGY	11	0.635
HARVARD BUSINESS REVIEW	11	0.635
JOURNAL OF COMPUTER ASSISTED LEARNING	11	0.635
LEARNING MEDIA AND TECHNOLOGY	11	0.635
ONLINE INFORMATION REVIEW	11	0.635
EDUCATIONAL TECHNOLOGY SOCIETY	10	0.578
FUTURES	10	0.578
HUMAN FACTORS	10	0.578

4.5. Distribution by subject category

Table 5 shows that "Psychology", "Computer Science," and "Information Science and Library Science," "Education Research," and "Business Economics," were the five most frequently used key words appearing in virtual worlds publications.

Table 5. Distribution by subject category

Subject Category	Record Count	%
PSYCHOLOGY	372	21.49
COMPUTER SCIENCE	321	18.544
LIBRARY SCIENCE	250	14.443
EDUCATION EDUCATIONAL RESEARCH	229	13.229
BUSINESS ECONOMICS	216	12.478
COMMUNICATION	167	9.648
ENGINEERING	147	8.492
GEOGRAPHY	76	4.391
ENVIRONMENTAL SCIENCES ECOLOGY	69	3.986
SOCIAL SCIENCES OTHER TOPICS	69	3.986
GOVERNMENT LAW	53	3.062
SOCIOLOGY	53	3.062
NEUROSCIENCES NEUROLOGY	38	2.195
NURSING	33	1.906
PSYCHIATRY	33	1.906
REHABILITATION	32	1.849
PUBLIC ADMINISTRATION	31	1.791

4.6. Distribution by authors

From the retrieved 1,731 literature entries between 1991 and 2011, we calculated the number of authors using the equality method; that is, each author in a multiple-author literature is regarded to have an equal contribution. There are a total of 3,557 authors with an average of 1.17 publications per person. The largest amount of literature published by one person is 25 publications (1 person). The number (4 people) of authors who produced more than 10 articles is quite small (only 3%). and there are 3,201 authors who only published one paper, which accounts for 89.99% of the total publications. The total published literature deduced from authors using the equality method should be 4,170; however, the actual number of literature entries is 1,731. It is estimated that each piece of literature is written by an average of 2.41 authors and that the size of each research team is two to three people. The people who published more than 10 literature pieces are Riva, G. (25 articles), Garcia-Palacios, A. (15 articles), Botella, C. (11 articles), and Hoffman, H.G. (10 articles).

The study of authors of virtual worlds literature between 1991 and 2011 can be explored using Lotka's Law. To validate whether Lotka's Law is applicable for virtual wolrds' literature, the slope value n and the constant value c should be calculated first, and a K-S test should then be performed to determine whether the distribution is in compliance with Lotka's Law (Bailón-Moreno et al., 2005). From the basic data, 89.99% of the authors have only one publication on virtual worlds in the last two decades studied; this result is different from the c value of 60.79% that appears in the original Lotka's Law. Therefore, the n value and the c value are calculated using the method of least squares to further examine their compliance with the Lotka's Law.

The calculated results in Table 6 are introduced into the calculation formula and the slope value n can be obtained as follows:

Table 6. Analysis of authors and their productivity of virtual worlds literature

x	y	X=log x	Y=log y	XY	XX
25	1	1.397940	0.000000	1.954236	0.000000
15	1	1.176091	0.000000	1.383191	0.000000
11	1	1.041393	0.000000	1.084499	0.000000
10	1	1.000000	0.000000	1.000000	0.000000
9	2	0.954243	0.301030	0.910579	0.287256
8	1	0.903090	0.000000	0.815572	0.000000
7	4	0.845098	0.602060	0.714191	0.508800
6	4	0.778151	0.602060	0.605519	0.468494
5	16	0.698970	1.204120	0.488559	0.841644
4	21	0.602060	1.322219	0.362476	0.796055
3	58	0.477121	1.763428	0.227645	0.841369
2	246	0.301030	2.390935	0.090619	0.719743
1	3201	0.000000	3.505286	0.000000	0.000000
Sum	**3557**	**10.175187**	**11.691138**	**9.637085**	**4.463360**

The calculated results in Table 6 are introduced into the calculation formula and the slope value n can be obtained as follows:

$$n = \frac{N\sum XY - \sum X \sum Y}{N\sum X^2 - (\sum X)^2} = -2.802 \qquad N = 13$$

After obtaining the slope, the n value is introduced into another formula, to obtain the c value:

$$c = \left(\sum_{x=1}^{p-1} \frac{1}{x^n} - \frac{1}{(n-1)p^{n-1}} - \frac{1}{2p^n} - \frac{n}{24(n-1)p^{n+1}} \right)^{-1} = 0.80223449 \qquad p = 13$$

When n= -2.802 and c=0.80223449, then f(x) = $0.80223449/x^{3.1015}$ can be deduced. For n and c values, the n value is about -2 and the c value is 0.8079 in the original Lotka's Law, which indicates that the distribution of authors in virtual worlds literatures does not completely match with the original Lotka's Law.

Pao (1985) described a least-squares (LS) method for testing Lotka's law, and suggested the procedures for computing values of the exponent n and constant c and the subsequent Kolmogorov-Smirnov (K-S) goodness-of-fit test for conformity. Zabed Ahmed and Anisur Rahman (2009) found that the maximum likelihood (ML) is a good method and that there is a tendency for least-squares fits to overestimate the slope of the power law since the statistical fluctuations in the logarithms of the data are greater in the downward direction than in the upward one.

Therefore, the LS method is used to estimate the best- fitting value for the slope of a regression line which is the exponent n for Lotka's law. The slope is usually calculated excluding high productive authorship from the dataset. Since values of the slope change with different number of author data, several computations of n were made. The n value as 2.058 provides the best-fitting value for the dataset. The n value was also calculated by ML method using Latka program. The ß-value (the Lotka exponent) is 2.1569 for authorship data.

The K-S statistic was performed again to test the observed and estimated values of LS n = 1.9022. The maximum absolute difference Dmax is 0.845 which falls outside the critical value of 0.0423 at 5% significance level. However, Kolmogorov-Smirnov statistics for n = 2.058 found D value 0.0389 which is max within the critical value at the 5% significance level. The Lotka program for K-S statistics for ML distribution is 0.0257 which is also below the 5% critical value of significance and hence, both should be accepted as appropriate models for the dataset.

The results suggest that author productivity distribution predicted in Lotka's generalized inverse square law is not applicable to virtual worlds research of SSCI database. Using Least-squares excluding high productive authors and maximum likelihood methods, Lotka's law is found to be applicable to virtual worlds research of SSCI.

5. Conclusion

To gain a clearer insight into virtual worlds' trends, forecasts and contributions, bibliometric methods was applied in this research. This study reveals that the topic of virtual worlds has been a subject with a rapidly growing literature base after analysis of the characteristics of all of the types of literature and the distribution of author productivities. Moreover, the literature on the subject of virtual worlds continues to grow, which implied that virtual worlds will continue to innovate and diffuse and that it will quickly be assimilated into our daily lives.

According the analysis, several findings would be discussed as followings: First, virtual world is more than a mere computer game, but it is an extension of users' real life due to a growing number of users worldwide and more advanced 3D open environment, such as Second Life, which is widely considered as the most advanced virtual world currently (Partala, 2011) with increasing volume of relevant researches in recent years.

Secondly, the major research institutions and literature production are mainly in the USA as well as authors' institutions in this country. Thirdly, virtual worlds' technology has been mainly applied into some main subject area such as Psychology; Computer Science, Library Science, Education Research, and Business Economics. Finally, the collaboration style of research teams is estimated to include two to three people, and the distribution of author productivity is in compliance with Lotka's Law after using least-squares excluding high productive authors and maximum likelihood methods.

Lotka's law of author productivity is regarded as one of the classical laws of bibliometrics. This study indicated that Lotka's generalized inverse square law using "full productivity" of authorship is not applicable to virtual worlds literature of SSCI. Since virtual worlds are still in the early stages of development (Hua and Haughton, 2009), future research should be directed towards understanding authorship distributions within various sub-fields of virtual worlds, authorship patterns in monographs and other publication types, collaborative authorship, author affiliation, oriental name headings, etc.

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