Application of Bradford's Law to Human-Computer Interaction Research Literature

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ABSTRACT

Bradford's law is about scattering of literature in different information sources on a narrow subject. The present study serves as a test of the two formulations of Bradford's law, verbal and graphical, using 137120 articles published on Human-computer interaction (HCI) research in the journals index in Science Citation Index-Expanded during 1987-2011. The data is divided into five five-year spans so that comparisons can be made between the percentage errors for each five-year period. List of the core journals is also prepared for all the five blocks of five-year period. Number of journals and their titles in the core group indicates continuous change in focus in HCI research from one five-year block to the next. In addition, the applicability of Leimkuhler model was also tested with the present data. Neither the verbal nor the graphical formulation provides results that are consistent with the practical situation.

Keywords: Bradford's law, Bradford bibliograph, Bradford multiplier, Leimkuhler model, core journals, human computer interaction

1. INTRODUCTION

Human-Computer Interaction (HCI) is defined as 'a discipline concerned with the design, evaluation, and implementation of computing systems for human use and with the study of major phenomena surrounding them'. HCI can be viewed as two powerful information processors (human and computer) attempting to communicate with each other. The HCI focuses on the interactions between human users and computer systems, including the user interface and the underlying processes which produce the interactions. The contributing disciplines include computer science, cognitive science, human factors, software engineering, management science, psychology, sociology, and anthropology. ‘Early research and development in HCI was on issues directly related to the user interface. Some typical issues were the properties of various input and output devices, interface learnability for new users versus efficiency and extensibility for experienced users, and the appropriate combination of interaction components such as command languages, menus, and graphical user interfaces. Recently, the field of HCI has broadened and become more attentive to the processes and context for the user interface. The focus of research and development is now on understanding the relationships among users’ goals and objectives, their personal capabilities, the social environment, and the designed artifacts with which they interact. As an applied field, it is also concerned with the development processes used to create the interactive system and their values for the human user'.

2. LITERATURE REVIEW

The intellectual base of any discipline is revealed in its journal literature, which serves, among other things, as a vehicle for disseminating information, introducing innovations, and reporting the findings of research in the field. However, ‘the proliferation of journals and the consequent exponential growth of journal literature have laterally jeopardised their capacity to transmit information effectively and rapidly’. Bradford was first to observe a pattern in scattering of journal productivity of a given subject. Bradford’s law of scattering is based on the principle that every scientific field is related, however remotely, to every other field. Bradford observed that a pattern in scattering of journal productivity of a given subject. Bradford’s law states that “if scientific journals are arranged in order of decreasing productivity of articles on a given subject, they may be divided into a nucleus of periodicals more particularly devoted to the subject, and several groups or zones containing the same number of articles as the nucleus, where the number of periodicals in the nucleus and succeeding zones will be in a ratio of 1 : n : n². The constant n is the property of the collection of periodicals called the Bradford multiplier. The graphical formulation of Bradford’s law is obtained by plotting a curve in a
plane whose coordinates are the cumulative number of articles (in the y-axis) and the logarithm of the cumulative number of journals (rank of journals) in the collection (in the x-axis), where journals are cumulated from most to least productive. This curve has invariably an ascending shape, which after a certain point approaches a straight line. Such a graph is called as ‘Bradford Bibliograph’. ‘Bradford’s law has been used as an argument about how to build collections, how to select journals to be indexed in bibliographies, how to measure the coverage of bibliographies, how to solve practical problems related to information seeking and retrieval.’

Bradford examined two bibliographies prepared in the Science Library (Britain) on Applied Geophysics (1928-1931) and Lubrication (1932-1937). He identified three groups of periodicals in the list of periodicals ranked by diminishing productivity that produced approximately the same number of articles on the subject, but the number of periodicals in these three equi-productive zones increased by a constant factor. Vickery extended the verbal formulation to show that it can be applied to any number of zones of equal yield, not to only the three zones that Bradford had used for his data. Stevens found in Chemistry that 2 journals were needed to cover 25 %, 7 to cover 50 % and 24 to cover 75 % of the total 247 journals covering 3633 citations. Leimkuhler suggested a model based on Bradford’s law of scattering and it is called the Bradford’s distribution. Brookes also derived a formula which does not depend on groupings of journal titles. Gross observed a droop while plotting the data on the journal literature of Physics. The droop refers to the shape of some Bradford’s curves at their tail ends. The curve shows a downward deviation at the end of the log-linear portion. This phenomenon is known as the ‘Gross droop’.

Goffman & Morris showed that Bradford’s law held good for literature, dispersion in the field of transplantation-immunology for the years 1965-1968, as well as periodical circulation in a medical library. Chakraborty studied the scatter of Indian geological literature in Indian and foreign periodicals and found that about 90 % of the literature is covered in Indian sources. Garvey pointed out that authors would seek to publish their articles in certain journals and not in others. Eto tested the applicability of the Bradford’s law to firms expending on the R&D and successfully identified core firms, peripheral firms, and minor firms. Brookstein observed the multidisciplinary character of journals and defined a simple model that indicates the evaluation of journals as a competition among subjects for space. Rao pointed out that value of Bradford multipliers vary from zone to zone. Bandopadhyay studied the scatter of journal literature in different disciplines for the period 1981 to 1990. Egghe has given ‘a note on different Bradford multipliers’ showing that the multiplier k that appears in the law of Bradford is not the production of articles per author nor the average number of μ of articles per journal. However, the Bradford multiplier may be close to μ in many cases.

Now a day, most of the studied are being carried out to test the applicability of Bradford’s law to literature related to various field of sciences. Some of the recent studies are mentioned here. Sudhier carried a study on five-year data of journals (2004-2008) cited by the physicists at the Indian Institute of Science to examine the applicability of Bradford’s law of scattering, from 79 doctoral theses during the period 2004-08. The journal distribution pattern did not fit the Bradford’s distribution pattern. Wardikar & Gudadhe carried a study on the data of journals cited by PhD. research scholars at the universities in Maharashtra for their doctoral research in the field of library and information science from 1982-2010. Annals of Library Science and Documentation took top place with 207 citations followed by College and Research Libraries with 184 citations and Herald of Library Science with 160 citations were the most preferred journals. Ram & Paliwal applied Bradford’s law of scattering to the Psoriasis literature published during 1960-2009 and found that the theoretical aspect of Bradford law did not fit, but the Leimkuhler model holds good for Psoriasis literature.

3. OBJECTIVES

(i) To examine the applicability of Bradford’s law of scattering to the pattern of journals productivity used by the researchers in field of HCI,

(ii) To identify the Bradford zones in the HCI literature used by researchers,

(iii) Test the applicability of Leimkuhler’s model, on HCI literature journal productivity data.

4. METHODOLOGY USED IN APPLICATION OF BRADFORD’S LAW

Data for the present study is downloaded using principal keywords related to HCI research from Science Citation Index-Expanded for the period 1987-2011. The data were divided into five data sets of five-year period blocks, i.e., 1987-1991, 1992-1996, 1997-2001, 2002-2006 and 2007-2011. Journal titles were sorted in descending order of productivity. The verbal formulation of the Bradford’s Law of Scattering is tested by dividing the total number of articles in each field into three zones. To test the graphical formulation of the Bradford’s law, Bradford bibliograph were plotted for each period block.

Leimkuhler developed a model based on Bradford’s verbal formulation as:
Bradford's multiplier factor was arrived at by dividing the number of articles in every Bradford group (all these group of items being of equal sizes), and

\[ k = \frac{c}{r_0} \]

where, \( k \) : Bradford multiplier.

If the sources are ranked in decreasing order of productivity, than \( y_m \) is the number of items in the most productivity sources (i.e., the source or rank 1); \( R(r) \) is the cumulative number of items produced by the sources of rank 1, 2, 3………r.

Once \( p \) is determined calculate the value of \( k \) by

\[ k = \frac{c}{r_0} \]

where, \( y_0 \) : Number of items in every Bradford group and \( r_0 \) : Number of sources in the first Bradford group.

Table 1 gives detail of Bradford zones for HCI research output during 1987-1991.

Table 2 gives detail of Bradford zones for HCI research output during 1992-1996.

Table 3 gives detail of Bradford zones for HCI research output during 1997-2001.
articles, which were divided into three zones. It results into relationship of each zone as 13 : 65 : 281. Here, 13 represent the number of periodicals in the nucleus and n= 4.65 is a multiplier. The mean value of multipliers is (5.0+4.3)/2=4.65.

Therefore, 1 : n : n^2 :: 13 : 13 x 4.65 : 13 x 4.652

:: 13 : 60.5 : 281.1 » 354.6

The percentage error = ((359-354.6)/359)*100

= 1.2 %

Table 4 gives detail of Bradford zones for HCl research output during 2002-2006. It has 37242 articles, which were divided into three zones as listed above. It results into relationship of each zone as 17 : 75 : 284. Here, 17 represent the number of periodicals in the nucleus and n= 4.1 is a multiplier. The mean value of multipliers is (4.4+3.8)/2 = 4.1.

Therefore, 1 : n : n^2 :: 17 : 17 x 4.1 : 13 x 4.12

:: 17 : 69.7 : 285.8 » 372.5

The percentage error = ((399-372.5)/399)*100

= 6.6 %

Table 4. Bradford’s zones for HCl research output during 2002-2006

<table>
<thead>
<tr>
<th>Zones</th>
<th>No. of articles (%)</th>
<th>Journals (%)</th>
<th>Bradford multipliers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12493 (33.5 %)</td>
<td>17 (4.3 %)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>12243 (32.9 %)</td>
<td>75 (18.8 %)</td>
<td>4.4</td>
</tr>
<tr>
<td>3</td>
<td>12508 (33.6 %)</td>
<td>284 (71.2 %)</td>
<td>3.8</td>
</tr>
<tr>
<td>Total</td>
<td>37242 (100 %)</td>
<td>399 (100 %)</td>
<td></td>
</tr>
</tbody>
</table>

Table 5 gives detail of Bradford zones for HCl research output during 2007-2011. It has 49286 articles, which were divided into three zones as listed above. It results into relationship of each zone as 29 : 88 : 355. Here, 29 represent the number of periodicals in the nucleus and n= 3.5 is a multiplier. The mean value of multipliers is (3.0+4.0)/2=3.5.

Therefore, 1 : n : n^2 :: 29 : 29 x 3.5 : 29 x 3.52

:: 29 : 101.5 : 355.3 » 485.8

The percentage error = ((472-485.8)/472)*100

= 2.9 %

The percentage error for the initial period of 1987-1991 is negligible. It is also observed that, the number of periodicals contributing references to each zone increases by a multiplier of 3.75. Similar trend in observed in case of data relating to time period 1997-2001 and 2007-2011 with percentage error of 1.2 % and 2.9 % respectively. Whereas, the percentage error during the five-year period blocks of 1992-1996 and 2002-2006, is significantly higher at 9.5 % and 6.6 % respectively.

It is clear from Table 1 to Table 5 that there are very small number of journals in the nucleus and they are the most productive journals devoted to HCI research ranging from 3.6 % during 1997-2001 and 6.1 % during 1992-1996 and 2007-2011, of total journals in the respective five-year blocks. The second zone is represented by a large number of journals which share 17.8 % during 1992-1996 and 20.7 % during 1987-1991 of total cited journals and the last zone is represented by around 80 % of total cited journals for all the five year blocks. Each zone has approximately one third (1/3) of the total citations. Hence, the journal distribution as per the Bradford’s law reveals that there is a large difference in Bradford multiplier for the period block of 1992-1996 as compared to the other period blocks. Although, difference in the Bradford multiplier for other year blocks is much less, it is still far from the ideal one.

5.2 Graphical Formulation

The graphical approach was developed by Brookes which tries to verify the verbal formulation of the Bradford’s law. The graph should display three distinct regions:

(i) Initially a rapid rise, indicating core journals whose points lay on the initial curved part of the graph until tangentially becomes a straight line

(ii) Then a big portion of linear rise, and

(iii) A ‘droop’ towards the tail, Brookes argued that droop was an indication of the incomplete nature of the bibliography examined.

5.3 Application of Leimkuhler Model

Leimkuhler’s model is applied on the data on all the HCI research for five five-year period blocks. K-S goodness-of-fit statistical test is applied to assert that the observed productivity distribution is not significantly different from a theoretical distribution. K-S test compares cumulative observed and cumulative expected frequencies of productivity distribution. The maximum deviation between the cumulative proportions of the observed and theoretical frequency is determined by the following formula:

$$D_{max} = \max \left| F_0 - F_e \right|$$

where, $F_0$ is the theoretical cumulative frequency; and $F_e$ is the observed cumulative frequency.

The K-S test is performed at 0.01 level of significance. Results of the K-S test are given in Table 6. For all the five period blocks, the $D_{max}$ value is more than the tabled K-S value at the 0.01 level of significance and hence Leimkuhler’s model has not been able to explain the scattering of journal productivity in HCI literature.

5.4 Core Journals

Number and type of journals in the core group are indicative the focus of the subject at for period of study. Core journals for the entire five five-year span are listed in Appendix I. The core journals for the period 2007-2011 are Expert Systems with Applications as top ranked, which followed by Bioinformatics; Neurocomputing and Pattern

Table 6. Value of the parameters obtained from the application of Leimkuhler law for the journal productivity distribution of HCI research

<table>
<thead>
<tr>
<th>Dataset</th>
<th>$k$</th>
<th>$r_0$</th>
<th>$y_0$</th>
<th>$A$</th>
<th>$b$</th>
<th>$D_{max}$</th>
<th>Critical K-S value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987-1991</td>
<td>11.89</td>
<td>1.219</td>
<td>1668.0</td>
<td>1551.6</td>
<td>8.928</td>
<td>0.2705</td>
<td>0.1189</td>
</tr>
<tr>
<td>1992-1996</td>
<td>12.14</td>
<td>1.957</td>
<td>5647.3</td>
<td>5209.1</td>
<td>5.691</td>
<td>0.3134</td>
<td>0.0920</td>
</tr>
<tr>
<td>1997-2001</td>
<td>21.03</td>
<td>0.754</td>
<td>9548.7</td>
<td>7188.1</td>
<td>26.92</td>
<td>0.3017</td>
<td>0.0860</td>
</tr>
<tr>
<td>2002-2006</td>
<td>20.37</td>
<td>0.914</td>
<td>12414.7</td>
<td>9483.7</td>
<td>21.19</td>
<td>0.3193</td>
<td>0.0816</td>
</tr>
<tr>
<td>2007-2011</td>
<td>17.13</td>
<td>1.515</td>
<td>16428.7</td>
<td>13316.8</td>
<td>10.64</td>
<td>0.3603</td>
<td>0.0750</td>
</tr>
</tbody>
</table>
Recognition; etc. When these titles are compared with the list of core journals for the earlier periods, it is observed that these journals have been going up steadily in the rank list. So, it can be implied that the field of HCI research is evolving continuously and that its focus is shifting over different periods of the study.

6. CONCLUSIONS

‘The principal application of Bradford’s Law is probably only in organising and presenting data on subject literatures, for example, for the evaluation of search results, for the comparative study of subjects, and for scientometric investigations.’ \(^{26}\) The journal distribution pattern of the HCI research during 1992-1996 and 2002-2006 does not fit the Bradford’s distribution pattern, i.e., \(1 : n : n^2\) as the percentage of error is very high (6.6 % and 11.3 %). For the period blocks of 1987-1991, percentage error is negligible at 0.05 %. For block period of 1997-2001 and 2007-2011, the percentage error is 1.2 % and 2.9 % respectively, which is not significant. Bradford’s multipliers have different values for different zones as well as different data sets. This is consistent with Roa’s\(^{19}\) view, that Bradford's multipliers vary from zone to zone. It is also observed from the Bradford multiplier that the number of journal in each zone is not increasing geometrically. Hence, it is concluded that the dispersion of journal titles in HCI literature does not satisfy the verbal formulation of Bradford’s law of scattering.

From the Figs. 1-5, it is found that the data in HCI literature for the entire five five-year period blocks, have an initial raising curve and followed by linearity, except towards the end showing a ‘droop’ characteristic of incomplete data. This droops have also been reported by Afioabi\(^{27}\) for library science literature. Leimkuhler model has failed to explain journal productivity distribution in the field HCI research, as values of \(D_{max}\) is much higher than the K-S critical values for all the five data sets.

Core journals of all five five-year period block are listed in Appendix I. The number of core journals is increased from 10 during 1987-1991 to 29 during 2007-2011. This indicates the gradual expansion of the field HCI research. Careful examination of the titles of sources indicates a constant shift in the focus of the literature in the field of HCI research. This has a the implication that extreme care should be taken while deciding the core journals for a narrow subject, otherwise it could lead to a selection sources which are not in use currently.

From the above discussion it is concluded that the journal usage pattern in HCI literature does fully satisfy either the verbal or the graphical formulation of the Bradford’s law of scattering. This may be due to the heavy concentration of articles in a few journals. The productivity of journals in HCI literature shows the concentration of more number of articles in a few journals.

REFERENCES


**About the Author**

Shri Suresh Kumar is working as Senior Technical Officer at National Institute of Science Technology and Development Studies (NISTADS), CSIR, New Delhi. He obtained his MLIS from Annamalai University, Tamil Nadu. He has more than 50 research paper to his credit. His research interests include: Citation analysis, scientometric studies, growth of literature studies, bibliometric distribution, and modeling studies.
### Core journals in HCI research during 1987-1991

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Journal title</th>
<th>No. of articles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Lecture Notes in Computer Science</td>
<td>943</td>
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<tr>
<td>2.</td>
<td>Computers &amp; Industrial Engineering</td>
<td>122</td>
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<tr>
<td>3.</td>
<td>IEEE Transactions on Systems Man and Cybernetics</td>
<td>89</td>
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<tr>
<td>4.</td>
<td>Sigplan Notices</td>
<td>79</td>
</tr>
<tr>
<td>5.</td>
<td>Computer Methods and Programs in Biomedicine</td>
<td>77</td>
</tr>
<tr>
<td>6.</td>
<td>Information Systems</td>
<td>77</td>
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<tr>
<td>7.</td>
<td>Neural Networks</td>
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<tr>
<td>8.</td>
<td>IEEE Transactions on Software Engineering</td>
<td>74</td>
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<tr>
<td>9.</td>
<td>Microprocessing and Microprogramming</td>
<td>73</td>
</tr>
<tr>
<td>10.</td>
<td>Pattern Recognition</td>
<td>71</td>
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</table>

### Core journals in HCI research during 1992-1996

<table>
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<th>Journal title</th>
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<tr>
<td>1.</td>
<td>Lecture Notes in Computer Science</td>
<td>1004</td>
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<td>IFIP Transactions A-Computer Science and Technology</td>
<td>508</td>
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<td>3.</td>
<td>Pattern Recognition</td>
<td>367</td>
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<tr>
<td>4.</td>
<td>Fuzzy Sets and Systems</td>
<td>359</td>
</tr>
<tr>
<td>5.</td>
<td>Neural Networks</td>
<td>303</td>
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<tr>
<td>6.</td>
<td>IEEE Transactions on Neural Networks</td>
<td>282</td>
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<td>7.</td>
<td>Lecture Notes in Artificial Intelligence</td>
<td>282</td>
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<td>8.</td>
<td>IEEE Transactions on Knowledge and Data Engineering</td>
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<td>IEICE Transactions on Information and Systems</td>
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<td>10.</td>
<td>Computers &amp; Industrial Engineering</td>
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<tr>
<td>11.</td>
<td>Expert Systems with Applications</td>
<td>244</td>
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<tr>
<td>12.</td>
<td>Journal of Chemical Information and Computer Sciences</td>
<td>229</td>
</tr>
<tr>
<td>13.</td>
<td>Decision Support Systems</td>
<td>211</td>
</tr>
<tr>
<td>14.</td>
<td>Pattern Recognition Letters</td>
<td>205</td>
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</table>

### Core journals in HCI research during 1997-2001

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<th>S. No.</th>
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<td>1.</td>
<td>Worldwide Computing and its Applications</td>
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<td>2.</td>
<td>Pattern Recognition</td>
<td>812</td>
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<td>429</td>
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<td>Theoretical Computer Science</td>
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<td>IFIP Transactions B-Applications in Technology</td>
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<td>15.</td>
<td>Engineering Applications of Artificial Intelligence</td>
<td>176</td>
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<td>Computer Methods and Programs in Biomedicine</td>
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<td>17.</td>
<td>Computer Networks And ISDN Systems</td>
<td>173</td>
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### Core journals in HCI research during 2002-2006

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Journal title</th>
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<tr>
<td>1.</td>
<td>Topics in Artificial Intelligence</td>
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<td>1266</td>
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### Core journals in HCI research during 2007-2011

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