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Proposal of INDIRECT X Mentions as an Altmetrics Indicator: Dissemination of Research Papers on X via Web News and Blogs

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Abstract

This study reconsiders altmetrics as an indicator for measuring the societal impact of research, specifically focusing on X (formerly Twitter). Current X data is aggregated based on posts containing direct hyperlinks to academic resource, which are first-order citations. In this research, we propose the indicator "INDIRECT X mentions" to capture the dissemination of research through second-order citations via intermediary webpages, such as news article or blogs that describing and linking to the resource. We also compare and validate its effectiveness against existing indicators. Focusing on the AI field, we conducted an analysis using data from one and a half years after publication. The results show that second-order citations allow for measuring the societal impact of papers over a longer period and form a distinct network with almost no overlapping users with the existing networks. Furthermore, the number of intermediary webpages strongly influencing "INDIRECT X mentions" deviates from the overall number of backlinks on the web. A comparison of language proportions also revealed that the proportion of Japanese-language intermediary webpages was significantly lower.

Introduction

The evaluation of academic research has traditionally been based on citation counts and citation-based metrics. These indicators have been widely used not only in academia but also in policymaking. However, concerns have been raised regarding their reliability, time lag before citation counts accumulate and inability to measure the societal impact of research beyond the academic community. Since the 2000s, the widespread use of the Internet has led to increase the need for new evaluation metrics, and J. Priem et al. (2010[a]) proposed the concept of "altmetrics." Today, platforms such as Altmetric.com and PlumX provide real-time indicators beyond citations for assessing research impact.

Among altmetric data sources, X (formerly Twitter) has drawn particular attention due to its data scale and potential as an indicator for measuring the societal impact of research (Wouters, P., et al., 2019). Notably, academic discussions on X have been increasing, and further enhancing its value as a data source (Yu, H., et al., 2019).

J. Priem et al. (2010[b]) stated that the dissemination of academic papers on X involves first-order citations, which hyperlink directly to academic resources, and second-order citations, which hyperlink to intermediary webpages such as news articles or blogs that describe and link to the resources. They found that second-order citations account for up to 48% of mentions. However, existing altmetrics indicators focus exclusively on first-order citations, overlooking second-order citations dynamics.

This study aims to propose a new metric that accurately reflects the dissemination of academic papers on X by incorporating second-order citations. We refer to direct

dissemination through traditional academic platforms as "DIRECT X mentions", while indirect dissemination via intermediary webpages is termed "INDIRECT X mentions". We collect and analyze DIRECT X mentions and INDIRECT X mentions for AI-related papers over 1.5 years post-publication. By examining how papers spread through second-order citations—an aspect largely unexplored in previous studies—we assess the utility of INDIRECT X mentions as a novel metric. To achieve this, we address two research questions.

- RQ1: Can INDIRECT X mentions serve as a new indicator of a paper's social impact?
- RQ2: Are the Altmetrics News and Blogs data reliable?

Method for Collecting INDIRECT X mentions

The existing metric, DIRECT X mentions, counts the total number of posts, including their reposts and quotes, that hyperlink directly to the webpage of an academic resource.

Our new metric, INDIRECT X mentions, counts posts that contain hyperlinks to intermediary webpages that mention the academic resource, as well as their reposts and quotes. This allows INDIRECT X mentions to be aggregated in a manner similar to DIRECT X mentions.

A list of intermediary webpages, such as news articles and blogs that describe and link to academic resources, is aggregated as altmetrics News and Blogs data. By collecting second-order citations that hyperlink to these webpages, we can systematically quantify INDIRECT X mentions.

Data

Several data providers offer altmetrics data, with differences in their collection methods and coverage. Among them, Altmetrics.com is known for its comprehensive coverage of X and webpage data (Ortega, J. L., 2018; Ortega, J. L., 2019; Zahedi, Z., et al., 2018). This study uses Altmetrics.com data to select target papers and refers to the existing X data as "DIRECT X mentions". This study is focusing on AI-related papers as a case study, given the high level of interest in AI research from both researchers and the general public. Papers in the AI field were identified using Altmetrics.com subject codes (4602, 4611) and keywords (AI, Artificial Intelligence, Deep Learning, GPT, LLM, Large Language Model). The selected papers were published between November 1, 2022, and April 30, 2023. For papers on arXiv, the publication date on arXiv was used as the original date. After removing duplicates, the top 100 papers were chosen based on DIRECT X mentions, counted 1.5 years after publication.

For intermediary webpages, News and Blogs data were collected for the 100 papers, duplicates were removed, and shortened URLs were resolved. The data with no URL was excluded, as it originated from non-web news sources such as newspapers. URLs duplicates were identified based on string match. As a result, 4,473 intermediary webpages were selected for analysis.

Next, using NodeXL, a network analysis tool for social media and web data, second-order citations were collected based on the aggregated intermediary webpage list.

Duplicate posts within the same article were excluded, and only posts within the aggregation period were considered. This resulted in 28,926 posts. INDIRECT X mentions were calculated by summing the number of posts, Reposts, and Quotes. Each dataset used in this study has slight differences due to the technical limitations of data collection. Specifically, in INDIRECT X mentions, the reposts and quote counts for second-order citations include posts from private accounts, whereas this is not the case for DIRECT X mentions. However, it was determined that these differences would not significantly affect the study's results.

For the time series analysis, cumulative data for INDIRECT X mentions was created based on post dates, while DIRECT X mentions were collected from the Altmetrics.com timeline. Due to limitations of the original data, the DIRECT X mentions timeline uses the reposted content date, while the INDIRECT X mentions data is added using the date of the original post.

For detailed network analysis, data from 17 selected papers out of the 100 papers were used, including only posts with hyperlinks. The INDIRECT X mentions network dataset contained 17,131 posts. For DIRECT X mentions, data were retrieved from Altmetrics API and X API. Some discrepancies occurred due to privacy settings and account deletions. Of 20,328 tweet_ids, detailed data was available for 20,107 posts. After filtering by date, 5,090 posts remained for analysis. To refine network analysis, DIRECT X mentions were recalculated using the same methodology as INDIRECT X mentions. This recalculated dataset is labelled as "DIRECT X mentions' " to distinguish it from the original data.

Can INDIRECT X mentions serve as a new indicator of a paper's social impact?

Score Distribution and Paper Classification

The minimum value for DIRECT X mentions was 252, while INDIRECT X mentions had a minimum value of 0, with 24 papers receiving no mentions. The first quartile for INDIRECT X mentions was 1, and the median was 90, showing most papers had low mentions. Both datasets had similar distributions, with maximum values of 7,308 (DIRECT X) and 8,625 (INDIRECT X), and interquartile ranges of 615 and 628.5, respectively. The analysis resulted in a Spearman's rank correlation coefficient of 0.53, indicating a moderate positive correlation, though not a strictly proportional relationship. The papers were classified into four quadrants based on the average values of DIRECT X mentions and INDIRECT X mentions (Figure 1): Q1 contained 11 papers, Q2 had 13, Q3 had 64, and Q4 had 12. While Q1 had a limited number of papers, 25 outliers were evenly distributed between Q2 and Q4. Meanwhile, 64 papers were categorized in Q3, indicating an appropriate skew in distribution. The scatter plot revealed a contrasting pattern cantered around $y = x$, supporting the Spearman correlation coefficient of 0.53, which suggests a weak proportional relationship between DIRECT and INDIRECT X mentions. However, the balanced distribution indicates the usefulness of INDIRECT X mentions as an independent metric. Furthermore, the results suggest that a previously overlooked social impact exists at a comparable scale through second-order citations, highlighting 12 papers in Q4 that were not adequately assessed by existing indicators.

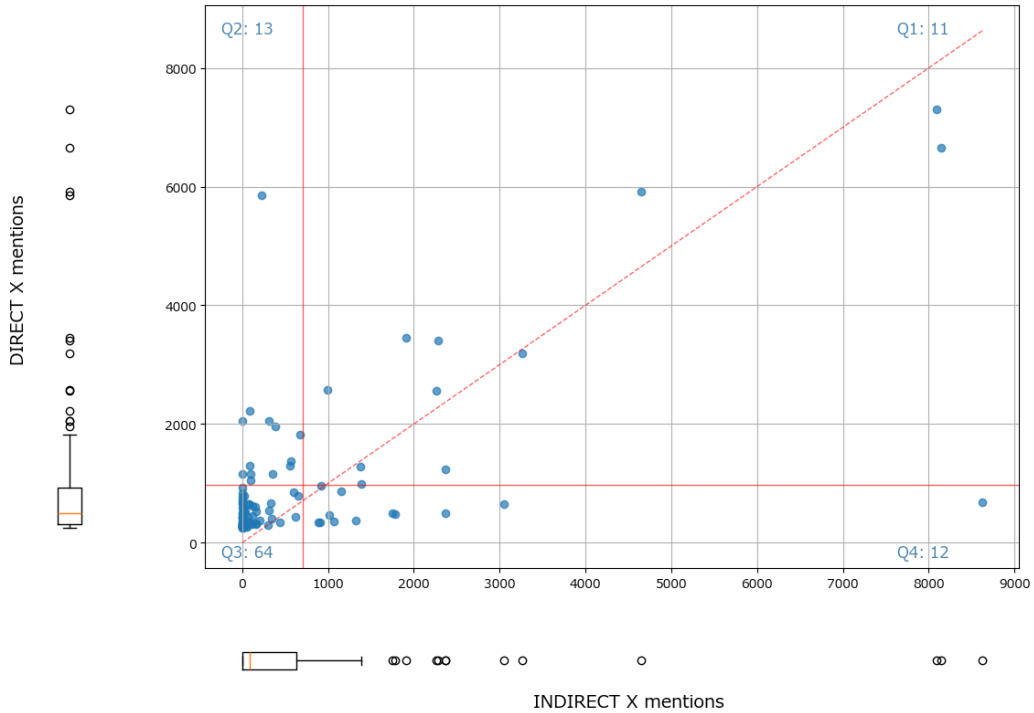

Figure 1. Distribution and Classification of DIRECT/INDIRECT X Mentions.

Time Series Analysis

A time series analysis of DIRECT X mentions and INDIRECT X mentions was conducted to examine their immediacy and long-term influence. One of the features of altmetrics is its rapid response. According to Priem et al.(2010[b]), 15% of first-order citations on X occur on the same day, and 40% occur within a week. In our analysis, 30% of DIRECT X mentions showed a response on the same day, and 90% within a week, while INDIRECT X mentions showed slower responses but still exhibited values comparable to Priem et al.'s findings. A detailed comparison revealed that 77% of papers exhibited a quicker response in DIRECT X mentions than in INDIRECT X mentions, with an average difference of 64 days. INDIRET X mentions may have a slight drawback in terms of immediacy.

To further assess the patterns the progression of DIRECT X mentions and INDIRECT X mentions towards their final scores s was competed. We analysed the data trends for each paper and calculated the median and average number of days to reach thresholds from 50% to 100% based on the final cumulative value. The results (Table 1) indicated that both indicators show a very rapid convergence compared to citation time lags, and INDIRECT X mentions tended to accumulate responses more slowly than DIRECT X mentions. This suggests that INDIRECT X mentions may take more time to gather reactions. Analyzing each paper individually, we found that INDIRECT X mentions tend to continue increasing independently over a long period, regardless of their score magnitude, unlike DIRECT X mentions. This suggests that

even after first-order citations have converged, second-order citations may play a role in maintaining the social impact of the paper.

Table 1. Elapsed days from publication date to threshold attainment date.

	Median		*Mean*	
	DIRECT X	INDIRECT X	DIRECT X	INDIRECT X
50%	7.00 日	41.50 日	42.50 日	103.87 日
60%	10.00 日	52.00 日	46.40 日	113.23 日
70%	12.00 日	76.00 日	59.00 日	127.50 日
80%	31.00 日	89.00 日	78.68 日	152.32 日
90%	66.50 日	127.00 日	125.38 日	188.36 日
100%	502.50 日	378.50 日	460.26 日	297.85 日

Network Analysis

To understand who posted direct or indirect mention, a network analysis based on DIRECT X mentions' (Group1), which recalculated DIRECT X mentions value based on post data obtained from the X API, and INDIRECT X mentions (Group2) was conducted. The 17 papers were randomly selected from each quadrant: 3 papers from Q1 (out of 11), 3 papers from Q2 (out of 13), 3 papers from Q3 (out of 64), and 8 papers from Q4 (out of 12). To examine the network overlap between Group 1 and Group2, Jaccard's Index was used. The results showed that the average Jaccard Index for all papers was 0.012 for Posting User (User who posted) and 0.031 for Referenced User (Referenced user in mentions, replies or quote), indicating a very small overlap. This suggests that the groups who posted or received of the posts of direct hyperlink to academic resource (Group1) and intermediary webpage (Group2) form independent networks.

The characteristics of both networks were analysed by combining data from all the papers. The analysis revealed that, for Posting User, In Group1, it was found that @arxivabs posted 801 posts which accounted for 20% of all posts. Furthermore, to examine users with greater influence, we looked at the X mentions scores for the top 20 users. The 20 users in Group2 accounted for 2.25% of all posts and 24.05% of the total INDIRECT X mentions, while the 19 users in Group1, excluding @arxivabs, accounted for 1.44% of all posts and 45.45% of the total DIRECT X mentions'. When examining Referenced User, it was found that many posts in both Group 1 and Group 2 referred to the same users. However, the most frequently mentioned users in both groups were different (Figure 2): Group 1 included 11 paper authors, 2 institutional accounts, 2 journal accounts, and 5 general users, while Group 2 included 14 news site accounts, 4 paper authors, and 2 corporate accounts. This suggests that Group 1 targets the academic community, whereas Group 2 is more associated with the news business community.

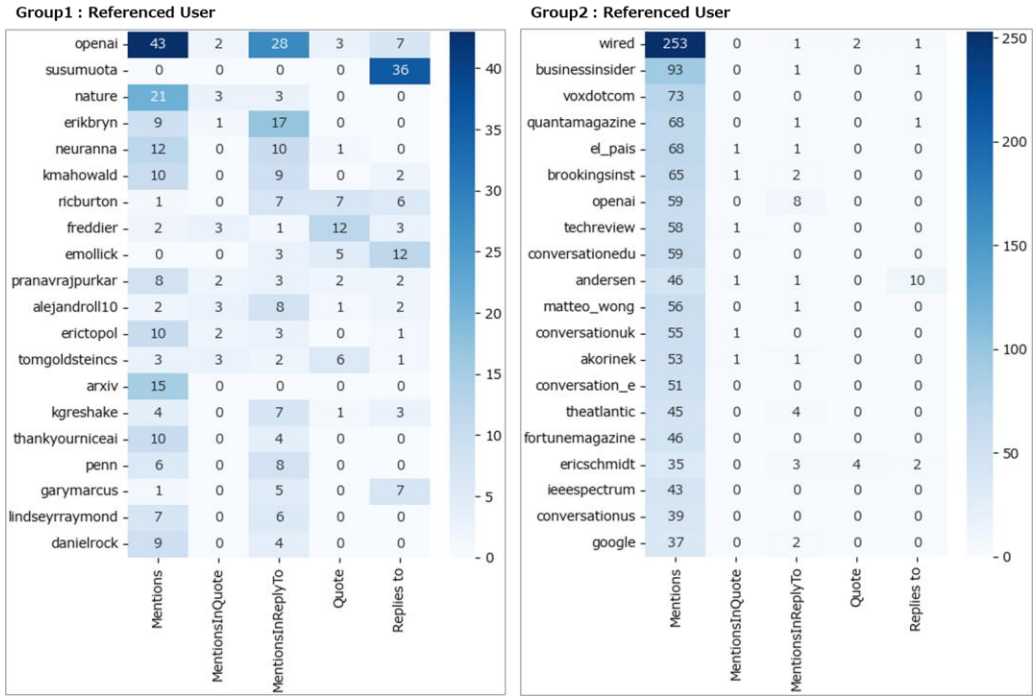

Figure 2. Top 20 Users by number of Referenced Nodes and post count by post types.

Are the Altmetrics News and Blogs data reliable?

Both DIRECT X mentions and INDIRECT X mentions exhibit large fluctuations in values, and no significant correlation was observed. However, INDIRECT X mentions tend to depend on the number of intermediary webpages, so if the number of intermediary webpages is 0, INDIRECT X mentions must be 0. Analysis using Spearman's correlation coefficient showed a strong positive correlation of 0.88 between INDIRECT X mentions and the number of intermediary webpages. In other words, to accurately collect INDIRECT X mentions as proposed in this study, intermediary webpages must be accurate. Currently, News and Blogs data is not automatically tracked for all web sources, but is tracked for those listed in Altmetrics.com's unique site list. While this method ensures the quality of intermediary webpages, it also carries the risk of reducing data collection quality if the site list is incomplete.

Backlink Count Investigation

To verify the reliability of webpages, the number of backlinks for papers with 0 webpages (18 papers) was investigated. Although this investigation includes all backlinks from sources other than news sites and blogs, it revealed that all the papers had numerous backlinks. The number of backlinks ranged from a minimum of 16 to a maximum of 391, with eight papers having more than 100 backlinks. This result strongly suggests that these 18 papers likely have webpages with non-zero values, implying that the current source list or judgment process may be incomplete.

Language Proportion Analysis

Previous research has shown that news and blog data are heavily biased toward English. Although Altmetrics.com has been found to be superior to other data providers in multilingual data collection, we have to examine the language disparities. Due to data limitations, network data from 17 papers was used (DIRECT X mentions'). The analysis revealed that, as in previous studies, English accounted high proportion in all categories. The proportion of Japanese was 1.44% (ranked 6th) in intermediary webpages, 9.40% (ranked 2nd) in INDIRECT X mentions, and 23.22% (ranked 2nd) in DIRECT X mentions. The high proportion of DIRECT X mentions suggests a strong interest in the field of generative AI research within the Japanese-speaking community. In fact, a survey conducted during the data collection period indicated that Japan ranked 3rd in access share to Openai.com, accounting for about 7%, confirming strong interest in generative AI. Furthermore, Japan ranks 2nd in X (formerly Twitter) usage, just behind the United States, suggesting that the data from DIRECT X mentions likely reflects actual language proportions. Given these findings, the low proportion of Japanese in webpages points to a possible inadequacy in Altmetrics.com's data collection methods for Japanese data.

Conclusion

This study attempted to quantify the dissemination of research papers through second-order citations using INDIRECT X mentions and examined whether it serves as a useful new metric, capturing the social impact of papers that traditional DIRECT X mentions may overlook. The results showed INDIRECT X mentions can reveal papers that were significantly disseminated through second-order citations but were not captured by DIRECT X mentions. The time series analysis indicated that, while INDIRECT X mentions—being citations propagated through webpages—lack immediacy, they continue to generate discussions beyond the initial day of citation, reflecting sustained interest in the research.

Network analysis suggested that second-order citations form an independent network with minimal overlap with first-order citations, suggesting that paper dissemination likely occurs in a broader scope, different from the follower-following relationships on X. Furthermore, while first-order citations primarily involve users from the academic community, second-order citations target the news industry community, indicating that second-order citations may be a useful metric for measuring social impact.

In conclusion, INDIRECT X mentions provide a more comprehensive measure of a paper's influence, offering researchers and policymakers a means to evaluate the societal reception of academic work. However, this study also has its limitations. Concerns remain regarding the reliability of webpage data. To ensure complete data coverage, future studies should incorporate web data from multiple platforms. Additionally, further research could explore the correlation between INDIRECT X mentions and academic success, their predictive value, and their potential as an indicator for measuring institutional research promotion efforts.

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