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Commemorating Judit Bar-Ilan
from bibliometric and altmetric perspectives

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This article commemorates the late Judit Bar-Ilan by illuminating her academic career from bibliometric and altmetric perspectives. We analyze Judit's publication output demonstrating her standing in the international scientometric community. Her co-authorship network spans 99 researchers from 27 countries. An analysis of title terms highlights how her research interest developed over the course of her 30-year career. As Judit was one of the "founding mothers" of the still young field of altmetrics, we also investigate how her publications were shared on social media. We group Twitter users into eleven user categories and analyze how those sharing the same publication are following each other. An analysis of the geolocations of Twitter users demonstrates that Judit's work was discussed worldwide, in particular in Europe and North America. The bibliometric and altmetric analyses confirm that Judit was an outstanding researcher, a supportive mentor and a great colleague. She will be missed.

Introduction

This article commemorates Judit Bar-Ilan, whom we considered a dear colleague and friend, by analyzing her work from both the bibliometric and altmetric perspectives. Originally a computer scientist and concerned with distributed computing and cryptography[1], Judit Bar-Ilan quickly became interested in using empirical methods to study the various aspects of scholarship online as well as the role of the Web for information retrieval (Thelwall, 2017). Her oeuvre is a true reflection of this interest.

Judit Bar-Ilan enjoyed collaboration very much and spent a significant amount of her time to serve the scholarly community. This is reflected in the leadership positions she has held in major national and international scientific organizations including the Association for Computing Machinery (ACM), Association for Information Science and Technology (ASIS&T), its Special Interest Group on Metrics (SIG/Met), Israeli Internet Society (ISOC-IL) and International Society for Scientometrics and Informetrics (ISSI). Judit was a member of several editorial boards including the Annual Review of Information Science and Technology (ARIST), Scientometrics, Cybermetrics, Online Information Review, Journal of Informetrics (JoI) and its new open access successor Quantitative Science Studies (QSS), Journal of the Association for Information Science and Technology (JASIST) and PLOS ONE. Judit Bar-Ilan also co-organized the altmetrics workshop series[2] and was founding member and editor in chief of the Journal of Altmetrics[3] founded in 2018.

We have had the great pleasure of working with Judit on altmetrics (Bar-Ilan et al., 2012; Haustein et al., 2014), a new research area in which she has played a significant role. This

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[1] See CV on her website: https://is.biu.ac.il/en/judit

[2] https://www.altmetrics.org

[3] https://www.journalofaltmetrics.org

paper analyses Judit's oeuvre from both a bibliometric and altmetric point of view, taking into account the multifaceted impact of Judit's research (Desrochers et al., 2018). We focus on analyzing her co-author network and the topics she has worked on during her career of 30 years (she published her first paper in 1989). We also incorporate a social-media based analysis by studying in-depth how Judit's articles were shared on Twitter. The Twitter analysis will reveal what types of users have shared her articles and how these are connected with each other. We will also present in which geographical regions her publications have been received as indicated by geo locations of Twitter profiles.

Methods
Bibliometric dataset
Bibliographic information was collected from Web of Science in August 2019 using the author search. A total of 131 documents were retrieved when searching for *AU=Bar-Ilan J*; these were verified intellectually and all of them could be assigned to Judit Bar-Ilan. We also confirmed that Judit never published under a different name.

Bibliometric networks
A co-authorship network was extracted from the bibliographic information using VOSviewer. Names of co-authors were cleaned using the VOSviewer thesaurus function. The following five author names had to be adjusted to merge different spelling variants: *Bar-Ilan, J*, *Moed, HF, Peritz, BC, Fink-Shamit, N* and *Ortega, JL*. VOSviewer was also used to extract a co-occurrence network of terms appearing in the titles of the 131 documents and to visualize Twitter follower networks.

Twitter dataset
Tweets linking to at least one of Judit's publications were retrieved via Altmetric. The bibliographic information from WoS was linked to Twitter data via the DOI, excluding 23 of 131 papers without a DOI. A total of 577 tweets sent by 464 users linking to 25 documents was extracted from a local copy of the database dated October 2018 in August 2019.

Categorizing Twitter users
Using grounded theory based on information available in users' Twitter bios, all Twitter users were assigned to at least one of the following eleven categories:
        a) Researcher,
        b) Professional or lecturer,
        c) Student,
        d) University or research center,
        d) Library or librarian,
        e) Outreach or journalist,
        f) Association or organization,
        g) Database or platform,
        h) Journal or publisher,
        i) Business or professional and
        j) Bot.
Allowing an overlap of categories was essential, since many Twitter users identify as belonging to more than one category (Haustein et al., 2016; Tsou et al., 2015). Users were coded by both authors. We analyzed the Twitter bio, the Twitter handle and, in certain cases, homepages linked to in the Twitter profile. Interrater reliability was assessed using Cohen's Kappa for each of the eleven categories (McHugh, 2012). After the first round of coding, disagreements were resolved for all cases assigned to categories with moderate level of

agreement (<0.60; that is, researcher, bot, university/research center, business/professional and association/organization, see Table 1).

Based on particular high interrater reliability during the first round of coding, it was comparatively easy to identify libraries or librarians (Cohen's Kappa=0.90), students (0.88) and professors or lecturers (0.85), while the highest disagreement between coders occurred for accounts categorized as associations or organizations (0.25) and businesses or professionals (0.30). During the second round of coding all accounts identified by one of the coders as researcher, bot, university/research center, business/professional or association/organization were revisited to resolve the disagreement. Resolving this disagreement increased Cohen's Kappa for all categories, so that after the second round of coding all user categories had a Cohen's Kappa of at least 0.73 (Table 1). For the 41 of the 464 cases for which disagreement was not resolved, accounts were assigned to any category selected by one of the coders. 95 accounts could not be classified due to lack of information.

Table 1. Interrater reliability before (round 1) and after (round 2) resolving disagreement.

User categories	Round 1				Round 2			
	Agreement	Disagreement	Percentage agreement	Cohens Kappa	Agreement	Disagreement	Percentage agreement	Cohens Kappa
Researcher	399	65	86.0%	0.58	464	0	100.0%	1.00
Professional/ lecturer	452	12	97.4%	0.85	458	6	98.7%	0.93
Student	461	3	99.4%	0.88	464	0	100.0%	1.00
University/ research center	444	20	95.7%	0.35	464	0	100.0%	1.00
Library/ librarian	452	12	97.4%	0.90	457	7	98.5%	0.94
Outreach/ journalist	438	26	94.4%	0.61	446	18	96.1%	0.73
Association/ organization	437	27	94.2%	0.25	464	0	100.0%	1.00
Database/ platform	445	19	95.9%	0.63	457	7	98.5%	0.88
Journal/ publisher	447	17	96.3%	0.62	457	7	98.5%	0.87
Business/ professional	418	46	90.1%	0.30	464	0	100.0%	1.00
Bot	459	5	98.9%	0.44	464	0	100.0%	1.00

Geolocation of Twitter users
The geolocation of Twitter users was determined for a subset of users, for which Altmetric provides latitude and longitude information. This information was converted into addresses using Google Maps to then extract city level information. For 346 out of the 464 users with a geolocation, 74 pointed to locations in the middle of countries to places with low or no population. As discussed previously (Haustein, 2019; Haustein & Costas, 2015), these are erroneous geotags, for which Altmetric could only determine the country or state instead of a more precise location. These geotags were considered in the country-level analysis but disregarded when analyzing user locations on the level of cities. The map displaying Twitter users in their location was created using ArcGIS online.

Twitter follower network

The follower network of the 464 users tweeting Judit's publications was created following the method by Alperin, Gomez and Haustein (2019). Using the tweet ID and Twitter user IDs, the followers and following were connected via the Twitter REST API. Nodes represent users tweeting one of Judit's articles and their followers. Arcs demonstrate the follower relationship with an outgoing arc (clockwise) indicating a following and an incoming arc representing a follower relationship. The network was visualized with VOSviewer.

Results

First, we will present the results of the bibliometric analysis of Judit Bar-Ilan's publications including co-authorship and keyword analysis. This is followed by an analysis of the relation between altmetric and bibliometric indicators. We conclude by interpreting the engagement with her publications on the social media platform Twitter.

Bibliometric analysis

The bibliometric analysis will focus on Judit's co-authorship network and an analysis of the topics she has covered in her publications, demonstrating who she collaborated with and the topics she worked on over her 30-year career.

Co-authorship analysis

Judit Bar-Ilan published 46 articles as single author and 85 articles in cooperation with at least one colleague. The majority of the single-authored publications deal with case studies, such as bibliometric analyses of topics (e.g., "Astrophysics publications on arXiv, Scopus and Mendeley: a case study"), databases (e.g., "Bibliometrics of "Information Retrieval" - A Tale of Three Databases") or people (e.g., "Eugene Garfield on the Web in 2001").
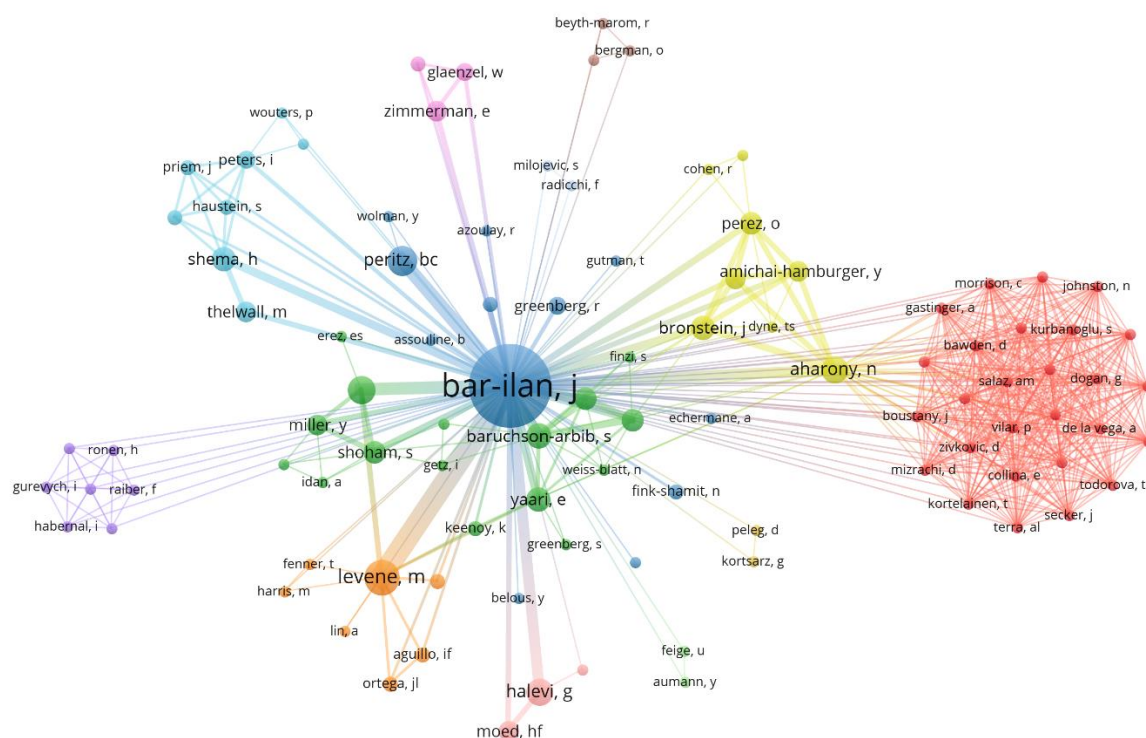

Figure 1. Co-authorship network of Judit Bar-Ilan

The co-authorship ego network contains Judit Bar-Ilan and 99 co-authors (Figure 1). With 33 of her co-authors she collaborated more than once. The list of collaborators include her seven PhD students (Thelwall, 2017), colleagues at Bar-Ilan University (e.g., Noa Aharony) and research project partners (e.g., Irina Gurevych, German-Israeli Project Cooperation). Judit collaborated most closely with Mark Levene (16 co-authored documents), Bluma C. Peritz (10) and Maayan Zhitomisky-Geffet (9). Fifteen clusters where identified, the largest of which (Figure 1, red cluster on the right) is based on one single publication with 32 authors[4]:

> Mizrachi, D., Salaz, A. M., Kurbanoglu, S., Boustany, J., & ARFIS Research Group. (2018). Academic reading format preferences and behaviors among university students worldwide: A comparative survey analysis. *PLOS ONE*, *13*(5), e0197444. https://doi.org/10.1371/journal.pone.0197444

The light blue cluster (Figure 1, top left) represents collaborations covering the area of altmetrics and scholarly communication via social media platforms (e.g., blogs). It is dominated by 6 publications Judit Bar-Ilan co-authored with her PhD student Hadas Shema. This cluster also contains a report on Next Generation Metrics in Open Science issued by the European Commission which also serves as policy citation for the article "Which h-index?— A comparison of WoS, Scopus and Google Scholar"[5]. Topically related is the publishing relationship with Wolfgang Glänzel and Eric Zimmermann (Figure 1, bottom center) as well as Henk Moed and Gali Halevi (Figure 1, top left).

Together with Bluma C. Peritz, Judit Bar-Ilan explored the Web as a source for bibliometric studies as well as the appearance of bibliometrics-related topics on the Web. They published ten papers together, especially in the years 1999 to 2009 (Figure 1, dark blue cluster in the center). This work has been continued with Judit Bar-Ilan's former student Gali Halevi and Henk Moed, which resulted in some studies on Google Scholar and, more recently, on the impact of retracted articles (Figure 1, pink cluster on the bottom).

Several clusters (Figure 1, dark blue, yellow, green) show that Judit Bar-Ilan was both nationally and locally well connected, within Israel and at the Bar-Ilan University (to whose eponym, she always emphasized, she was not related). Those clusters represent collaboration in research projects that are concerned with information behavior and information management (e.g., Noa Aharony, Department of Information Science, Bar-Ilan University), information need analyses (e.g., Shifra Baruchson-Arbib, Department of Information Science, Bar-Ilan University), information retrieval evaluation (e.g., Maayan Zhitomirsky-Geffet, Department of Information Science, Bar-Ilan University) and knowledge search (e.g., Ido Dagan, Department of Computer Science, Bar-Ilan University).

Interestingly, the co-authorship network and cluster analysis reveals that in the field of bibliometrics and altmetrics the collaboration was more internationally oriented, whereas Judit Bar-Ilan's work on search behavior, information management and information retrieval was influenced by colleagues working in close geographical proximity. Internationally, Judit

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[4] The ARFIS Research Group consisted of Tania Todorova, Pan Yantao, Jiuzhen Zhang, Daniela Živkovic, Darija Pešut, Terttu Kortelainen, Judit Bar-Ilan, Noa Aharony, Elena Collina, Liga Krumina, Hanady Geagea, Silvia Ghinculov, Ane Landøy, Almuth Gastinger, Aurora de la Vega, Ana Lúcia Terra, Nicole Johnston, Angela Repanovici, Polona Vilar, René Schneider, Güleda Dogan, Serap Kurbanoglu, Patricia Jamal, David Bawden, Jane Secker, Chris Morrison, A.M. Salaz, Diane Mizrachi, and Joumana Boustany.
[5] Bar-Ilan, J. (2008). Which h-index?—A comparison of WoS, Scopus and Google Scholar. Scientometrics, 74(2), 257-271. URL: https://doi.org/10.1007/s11192-008-0216-y. See also: https://plu.mx/mtsinai/u/jbarilan

collaborated with researchers from 27 different countries, most frequently with colleagues from the UK (22 co-publications), the US (13) and Italy (4). The remaining 24 countries were represented by one co-author each. On the level of institutions, the closest collaboration was with researchers from Hebrew University in Jerusalem (where she did her PhD), University of Haifa (where she served as a visiting lecturer) and Birbeck University London.

Analysis of topics covered in publications
During her career Judit Bar-Ilan has worked on a diverse set of topics. Figure 2 displays the co-occurrence of noun phrases that have appeared in the titles of publications authored by her. Node color indicates the average publication year of documents containing respective noun phrases from early works in dark blue to purple and most recent publications in light green to yellow. She has pioneered the exploration of the Web for bibliometric purposes (as shown in the center of the network), but she has also published on move choices of chess engines as well as on empirical studies on indicators and information retrieval (e.g., together with Mark Levene, University of London, isolated cluster on top left).

Figure 2. Co-occurrence of noun phrases appearing in titles of publications authored by Judit Bar-Ilan. Node colors indicate average year of publication of documents with respective title term.

By exploring Figure 2 in clockwise direction, the yellow-encircled cluster on the top left represents her latest work on information behavior, online forums, and lurking as well as on e-democracy and information behavior in political settings (such as political use of social media). The light blue cluster on the top right is concerned with information availability on the web as well as bibliometrics and informetrics; the dark blue cluster on the right is based on work on the usage of search engines, whereas the red cluster clearly focusses on the evaluation of search engines and information retrieval (including user satisfaction with ranked search results). The green-encircled cluster on the left depicts topics related to scholarly communication and citation analysis as well as altmetrics. It also contains papers on e-book-related user behavior, motivation and reading types. Lately Judit had also started to work on retracted articles, their effects in terms of citations and altmetrics and the reasons for retraction (Figure 2, bottom left of green cluster).

It becomes apparent that Judit Bar-Ilan's research topics strongly influenced her co-authorship network. Most likely this also provided for a diversification of the research methods used, for example citation analysis (Figure 2, green cluster), author co-citation analysis (Figure 2, light blue cluster) and modelling (Figure 2, yellow cluster). However, most of Judit's work is of empirical nature and includes data analyses or user studies.

Relationship of traditional and bibliometric indicators
Comparing the number of citations with social-media based engagement counts on the article level, two articles clearly stand out in terms of their number of citations and tweets: both articles focus on research blogging and are first-authored by Judit's former PhD student Hadas Shema (Figure 3, Table 1). The first article (#1, 79 citations in WoS, 282 tweets) was published in PLOS ONE and investigates research blogs in general, while the second study (#2, 86 citations, 66 tweets), published in JASIST, analyses whether blog citations can function as an early indicator predicting citations. Both studies were also frequently mentioned on blogs themselves.
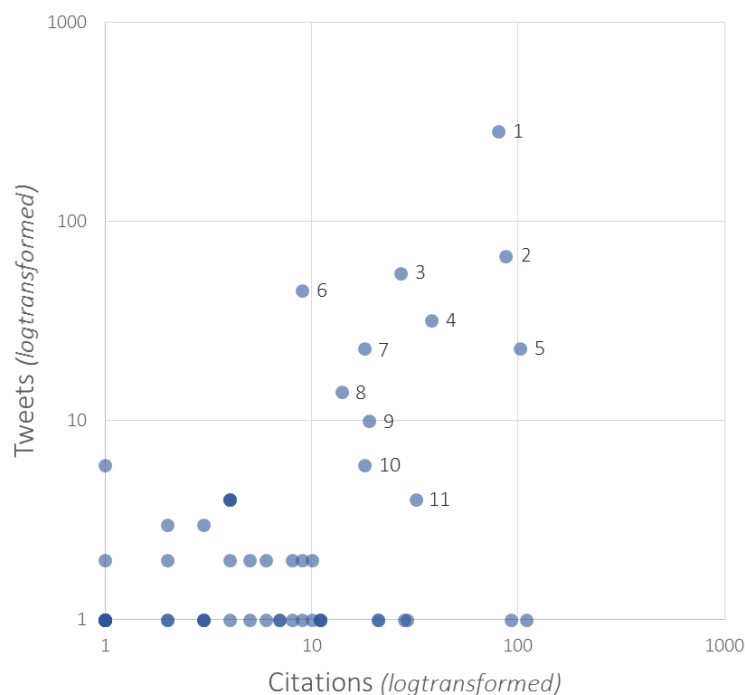

Figure 3. Scatterplot of number of citations and tweets for 57 publications. Labels indicate the rank of the publication in Table 1.

When comparing the number of tweets and citations on the article level, the Spearman correlation for the 57 publications found by Altmetric is $\rho=0.349$ ($p=0.008$), indicating a moderate correlation between the number of citations and tweets. Indeed, two of the three most frequently cited publications were never mentioned on Twitter. The WoS usage count and citations were correlated at $\rho=0.734$ ($p=0.000$)

When considering all 131 publications, including those not covered by Altmetric, Judit's most cited publication was about the h-index. Her solo-authored publication which appeared in *Scientometrics* in 2008, compared h-indices derived from data from WoS, Scopus and Google Scholar. The article was cited 320 times in WoS. Her second most frequently cited article received 179 citations and was also published by Judit alone: it is a review of "Informetrics at the beginning of the 21st century" published in *Journal of Informetrics*.

Table 2. Top 11 publications with highest number of citations and tweets with WoS usage, public Facebook posts and blog citations.

#	Title	Authors	Journal	Citations	WoS usage	Tweets	Facebook	Blogs
1	Research blogs and the discussion of scholarly information	Shema, H, **Bar-Ilan, J**, Thelwall, M	PLOS ONE	79	52	282	5	35
2	Do Blog Citations Correlate With a Higher Number of Future Citations? Research Blogs as a Potential Source for Alternative Metrics	Shema, H, **Bar-Ilan, J**, Thelwall, M	JASIST	86	92	66	1	10
3	A new methodology for comparing Google Scholar and Scopus	Moed, HF, Bar-Ilan, J, Halevi, G	JOI	26	47	54	0	0
4	Suitability of Google Scholar as a source of scientific information and as a source of data for scientific evaluation-Review of the Literature	Halevi, G, Moed, H **Bar-Ilan, J**	JOI	37	71	31	1	0
5	Coverage and adoption of altmetrics sources in the bibliometric community	Haustein, S, Peters, I, **Bar-Ilan, J**, Priem, J, Shema, H, Terliesner, J	Scientometrics	101	364	22	0	0
6	Citation success index - An intuitive pair-wise journal comparison metric	Milojevic, S, Radicchi, F, **Bar-Ilan, J**	JOI	8	21	44	0	1
7	How Is Research Blogged? A Content Analysis Approach	Shema, H, **Bar-Ilan, J**, Thelwall, M	JASIST	17	65	22	0	4
8	Folder versus tag preference in personal information management	Bergman, O, Gradovitch, N, **Bar-Ilan, J**, Beyth-Marom, R	JASIST	13	43	13	2	0
9	Psychological factors behind the lack of participation in online	Amichai-Hamburger, Y, Gazit, T,	Computers in Human	18	52	9	0	0

	discussions	**Bar-Ilan, J**, Perez, O, Aharony, N, Bronstein, J, Dyne, TS	Behavior					
10	Post retraction citations in context: a case study	**Bar-Ilan, J**, Halevi, G	Scientometrics	17	26	5	0	0
11	Information quality assessment of community-generated content - A user study of Wikipedia	Yaari, E, Baruchson-Arbib, S, **Bar-Ilan, J**	Journal of Information Science	31	53	3	0	0

Altmetric analysis

The analysis of impact of Judit's research on social media focuses on Twitter as one of the most popular altmetric data sources (Haustein, 2019). Querying Altmetric for DOIs, a total of 577 tweets sent by 464 users, linking to 25 documents was retrieved. As described in Figure 3 and Table 2 above, the most tweeted publications analyzed research blogs and were published in collaboration with Hadas Shema and Mike Thelwall. Another of Judit's research topics that was popular on Twitter was Google Scholar's suitability for research evaluation (#3, #4).

Twitter users categories

80% of Twitter users were categorized into eleven user types, while one fifth of the 464 accounts lacked sufficient information. As shown in Figure 4, the largest user group tweeting about Judit's journal articles were researchers (129; 28%), followed by librarians (79; 17%) and businesses or professionals (64; 14%). This emphasizes that Judit's work was relevant to both researchers and practitioners. The color coding in Figure 3 highlights that more than half (yellow, 54%) of Twitter users interested in Judit's work were members of the academic community. The second largest user community are databases and publishing platforms (pink, 16%), followed by the business sector (light blue, 14%) and journalists (green, 11%). Only 7 (2%) accounts were identified as bots, which is below the 12% reported for the 2,043 most active Twitter accounts captured by Altmetric (Haustein, 2019).

As discussed above, Twitter bios are often used to describe users as personas fitting into more than one of the eleven categories. 125 (27%) accounts were thus assigned to more than one category. The largest overlap can be found between databases/platforms and journals/publishers (36% of databases/platforms were journals/publishers), databases/platforms and business/professional (15%) as well as between researcher who also described themselves as active in outreach or journalism (12%). Universities/researcher centers represented the category with the least overlap with other categories.
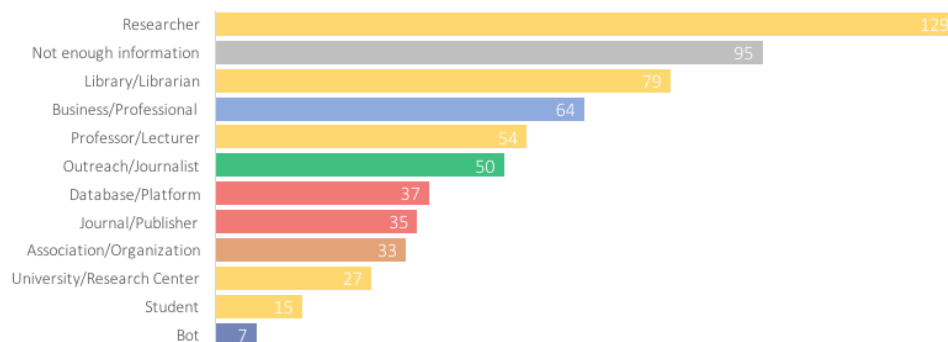

Figure 4. Twitter users per category (multiple assignment possible). Yellow: academia, light blue: business, green: outreach, red: publishing, orange: association, dark blue: bot, grey: unknown

Twitter user locations

Of the 464 Twitter users, 346 (74.6%) had a geo location assigned by Altmetric. This is slightly higher than the 67% found for all tweets captured by Altmetric (Haustein, 2019). The 346 users with geo locations in their Twitter profiles were located in 43 countries. Most of these users came from the United States (108), United Kingdom (55), Spain (33), Germany (22) and Canada (17). Surprisingly, only two users came from Israel, showing that Judit's publications were mostly perceived on international Twitter and less so in her home country. Judit did not tweet links to her own papers, probably because she was not very active on Twitter herself. Her Twitter profile @juditbi only follows seven accounts, has 77 followers and one tweet (in Hebrew) from when she joined Twitter in May 2009.[6]

Figure 5. World map of locations of Twitter users tweeting Judit's publications.

More detailed geo locations could be identified for 272 of the 346 users (78.6% of users with some geo information; 58.6% of all users), indicating that they lived in 171 cities according to their Twitter bio. London (18), Barcelona (9), Washington, DC (7), Philadelphia (5) and New York (5) were the most popular cities among the 272 users tweeting about Judit's publications. Figure 5 shows that most Twitter users sharing links to her papers were located in Europe and the East coast of the US.

Twitter user networks

The follower networks of users mentioning Judit's publications display the connections between Twitter users talking about the same content. Figure 6 shows the follower networks for the four articles with the highest number of tweets (Table 2, #1, #2, #3, #6). It can be seen in Figure 6 that the publication with the highest number of tweets (#1) has been tweeted by a network of followers that is well connected. Only one user is isolated and not connected to the largest component. The article on research blogging attracted relatively more students but less association, journal and university accounts than all of Judit's tweeted papers combined. Publication #2, which also discussed research blogs but rather from the perspective of their potential as altmetric indicators, attracted more professors and less associations (Figure 4). The article with the third largest number of tweets was particularly popular in the library

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[6] https://twitter.com/juditbi

community: 39% of accounts of mentioning this paper were run by librarians or libraries. The article introduced a new method to compare Google Scholar and Scopus. On average, it attracted less researchers and journal/publisher accounts and no outreach or association accounts. Interestingly, the network had only one component, which means that all users tweeting the article were already connected and thus part of the same online community. Therefore, the network density was also particularly high at 14%, compared to 11% for #2, 9% for #6 and 5% for #1. The fourth most frequently tweeted article authored by Judit introduced a new journal metric and was particularly popular among researchers (40%) and students (6%). It was less frequently tweeted among outreach, business, journal/publisher and association accounts.

Figure 6. Follower networks of Twitter users mentioning highly tweeted papers #1, #2, #3 and #6.

Conclusions

Our bibliometric analysis showed that Judit Bar-Ilan was a well-connected researcher with a large and diverse network of co-authors. She frequently collaborated with colleagues from her home university as well as with researchers from all over the world: her 99 co-authors were affiliated with institutions in 27 countries. Similarly, the altmetric perspective reveals that her publications were distributed widely on Twitter: 25 of her articles were tweeted. Users sharing her research came from 43 countries and were well connected on the microblogging site. Her work was particularly popular among Twitter accounts located in the US, UK and Spain on the country level and in London, Barcelona and Washington, DC on the level of individual cities.

Judit's articles covered a broad area of topics which can be summarized as "internet research". Her publications focus on "informetrics", "information retrieval" and "information behavior" – terms she has used herself to describe her research profile[7]. As shown by the classification of Twitter users, her work influenced both researchers and practitioners from the library and information science community and beyond. Judit's scientific contribution to the fields of information science and informetrics and her engagement in the community was recognized via several awards including the prestigious Derek De Solla Price Memorial Medal[8] in 2017. The bibliometric and altmetric analyses confirm that Judit was an outstanding information scientist, a supportive mentor and a great colleague. We will miss her.

Acknowledgements

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[8] http://issi-society.org/awards/derek-de-solla-price-memorial-medal/

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