REALM: An Altmetrics-based Framework to Map Science Impacts on Society. A Case Study on Zika Research

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ABSTRACT

Nowadays, a lot of universities and research institutes are concerned with measuring their scientists' productivity and the public awareness of its scientific discoveries, that is, how citizens interpret the efficiency of scientists and their efforts to find solutions. This scenario demands mechanisms to identify the experts' reputation in specific domains or topics of interest, such as the Zika epidemic. In this paper we describe an altmetrics-based framework which allows the identification of specialists and important research in specific research scenarios. Besides, we did an implementation of the framework and applied it in the Zika scenario where the most important names and disease-related studies were identified and their public awareness was analysed via altmetrics.

CCS CONCEPTS

• **Networks** → **Online social networks**; • **Human-centered computing** → **Social network analysis**; **Reputation systems**.

KEYWORDS

Altmetrics; Bibliometrics; Social network analysis; Zika; RDF

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1 INTRODUCTION

In some emergency scenarios, mainly when there is no solution created, greater collaboration among specialists is required. As an example, we can mention the Zika Virus (ZIKV) epidemic, whose epidemic potential became evident in 2014. In 2015, the outbreak had a high rate of occurrences in Brazil, affecting thousands of people and causing overcrowding of public and private emergency services, although it has not been measured by an official notification system at that time [38].

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Cases of microcephaly and neurological disorders in newborns occurred in Pernambuco and other states of the Northeast and, a posteriori, in the Southeast of the country, leading the Brazilian government to declare a State of Emergency in Public Health of National Importance in November 2015, and subsequently by the World Health Organization on February 1, 2016, a Public Health Emergency of International Concern (PHEIC) [25].

Because of the urgency for answers, science rushed into the investigation. To ensure that the international scientific community was able to make public the results and discussions on the theme, faster procedures were adopted for the approval and publication of articles on the subject, the so-called fast tracks. The demand for quick results also led many researchers to start showing their results on social media, not waiting for the time of conventional publications [13, 23]. Scenarios such as these provide an excellent opportunity to verify the reputation of experts, their scientific output and how the population interprets the solutions they create.

An effective way to analyze scientific production is through Social Network Analysis (SNA) metrics and the mapping of scientific collaboration networks, since collaboration is today an intrinsic feature of modern science. Thus, co-authorship is an important indicator of scientific collaboration in the understanding of several factors related to cooperation among specialists [20, 22].

In addition, new approaches to assessing scientific impact have been gaining ground in the proportion that scientists change their practices and ways of disseminating their research using the web as well [29]. As a result, alternative social impact-based metrics are being developed and tested [27]. This new form of measurement, also known as Altmetrics [31], incorporates the metrics of the previously mentioned studies and offers new alternative metrics (altmetrics) that allow mapping the correlation between researchers and society, which is increasingly improved through the exchange of experiences, reviews and content on social media, such as wikis, blogs and microblogs, online news, discussion forums, Online Social Networks (OSN), etc [9].

For Priem et al. [28] these new alternative metrics broaden our horizon about what the impact would be and what its real causes would be. Altmetrics can be used as a tool to support researchers, not only in their fields of work, but to maximize the influence and impacts of their research, so that it is possible to measure its relevance in an increasingly crowded universe of scientific works.

In this way, this work proposes the creation of a computational framework to measure the impacts of science in the present time, in order to understand the representativeness and recognition of the researchers before the society. The computational framework, called REALM (Researcher Evaluation ALternative Metrics), aims to

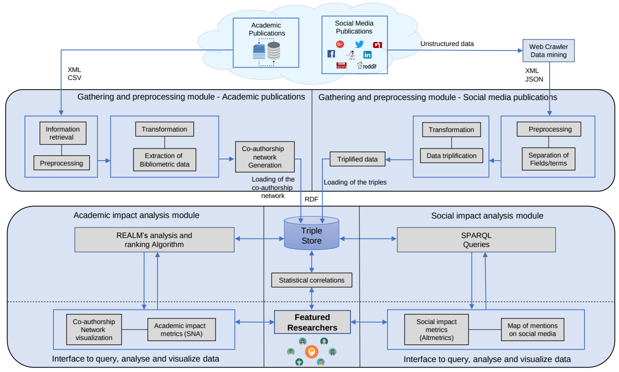

Figure 1: REALM architecture

identify the academic and social reputation of researchers and their research, based on alternative impact metrics. Besides, we did an implementation of the framework and applied it in the Zika scenario, where we tried to answer the following research questions: "who are the most influential scientists under the ACADEMIC perspective?" and "who are the most influential scientists under the SOCIAL perspective? ".

2 RELATED WORK

Empirical studies in the field of Altmetrics can be based on many kinds of platforms that allow the extraction of different groups of academic and social impact metrics. Among these platforms we can mention OSN like Facebook and Google+, scientific blogs (or blogs in general) and reference managers like Mendeley and CiteULike.

This way of quantifying science is supported by several empirical studies that aim to effectively demonstrate the impact of academic research on society in general. This perspective is addressed in the works of (i) Bornmann [10], with the use of three types of platforms: Twitter, the reference managers Mendeley and CiteULike, and scientific blogs; (ii) Hassan and Gillani [14], who proposed an altmetric study based on several platforms, such as Google Scholar, Twitter, Mendeley, Facebook, Google+, CiteULike, blogs, and Wiki; (iii) Kwak and Lee [19] which used Twitter; (iv) Mohammadi et al. [24] on Mendeley; and (v) Hoffman et al. [15] on Researchgate.

In terms of altmetrics, some systems like Altmetric (Altmetric.com) and Impactstory (Impactstory.org) are quite popular in regard to measuring the social impact of papers and researchers [34]. Altmetric is a commercial service that allows the tracking of millions of papers based on its online attention [1]. Impactstory allows the access of altmetrics only from works linked to a registered profile [30]. These systems, however, have several limitations, as they use only one type of measurement: mentions on social media. REALM stands out from the other systems for being free and for allowing the reputation analysis of researchers and research through three kinds of measurement: productivity (bibliometrics), academic impact (Social Network Analysis - centrality metrics) and social impact (mentions on social media - altmetrics), in a combined way. This analysis is two-fold: we analyze the academic reputation (based on the researcher's scientific production and relevance in his/her community) and the social reputation (based on the repercussion of his/her work on social media). Another advantage is the possibility of comparing the evolution of scientific domains based on temporal, geolocation and other macro aspects.

3 REALM: FRAMEWORK DESCRIPTION

REALM is divided in four modules: (a) Academic data collection and processing; (b) Social media data collection and treatment; (c) Academic impact analysis; (d) Social impact analysis. The system was implemented in the programming languages: PHP (native) with the library EasyRDF (easyrdf.org) version 0.9.0; Javascript (native) with the libraries Cytoscape.js (js.cytoscape.org) version 3.2.9, jQuery version 2.1.4, and Google Charts (developers.google.com/chart), in the GeoChart and BubbleChart types; HTML markup language; and framework CSS Bootstrap version 4.1. Its architecture (Figure 1) is described in Subsections 3.1 to 3.5.

3.1 Academic data collection and processing

This module is responsible for retrieving data from publications in indexing databases (e.g. PubMed, Web of Science, Scopus, etc.) to build Scientific Co-authorship Networks (SCN) [5, 18, 20, 21, 37] based on specific areas or topics of interest (e.g. neglected diseases such as Zika, Dengue or Chikungunya). The module operates extracting pieces of information from the publications such as title, authors name, affiliations, date of publication, article id, and others. Using this information, we identify the co-authorship networking. The main operations performed by this module are: (i) association of two nodes (authors), based on the title of a publication, characterizing an edge. (ii) Removal of edges without associated nodes. (iii) Representation of the social network described in item (i) using a matrix. (iv) Removal of duplicate items. (v) Identification of edges weight, based on the frequency of common co-authorship. (vi) Assignment of identifiers at each node and edge, allowing the reading and storage of SCN data in the database for later visualization of the co-authorship graph and extraction of academic impact metrics.

3.2 Social media data collection and treatment

This module is responsible for collection, preprocessing and triplification of data from social media publications such as online news, blogs posts, discussion forums, and OSN (e.g. Facebook, LinkedIn, Google+, etc.). The collection of these data is based on an implementation of the Webhose (webhose.io) API, which allows the monitoring of social media in real time and automatic collection of publications 24 hours a day. The configuration of specific queries in the code makes it possible the collection on specific topics of interest, extracting only posts related to certain themes (e.g. Zika, Dengue or Chikungunya). The collected data is in an unstructured format. Then, data is converted to the semi-structured format (JSON/XML) and the fields/terms of the posts, such as URI, title, text, author, country, domain, date, language, shares on OSN, and others are extracted. This output enables the extraction of altmetric indexes and, consequently, of social impact metrics. The next step is the triplification of data, which consists in the description of the data using RDF triples, based on the RDF data model available in: (realm0.github.io/1). The RDF triples format enables the insertion of new information in our model, the use of more complex search queries, and the extension of this approach for a further integration of data from other domains. Finally, the triples are stored in the Apache Jena Fuseki triplestore (jena.apache.org) for later extraction of the altmetrics.

```
Data: multidimentional array subnet, NP, NE
Result: multidimentional array ranked_subnet
ranked_subnet ← [];
foreach subnet as i do
    subnet[i]['deg'] ← degree(subnet[i]['node']) ; subnet[i]['bet'] ← betweenness(subnet[i]['node']) ;
    subnet[i]['clo'] ← closeness(subnet[i]['node']) ; subnet[i]['pag'] ← pagerank(subnet[i]['node']) ;
end
foreach subnet as i do
    subnet[i]['deg_pos'] ← position(subnet[i]['deg']) ; subnet[i]['bet_pos'] ← position(subnet[i]['bet']) ;
    subnet[i]['clo_pos'] ← position(subnet[i]['clo']) ; subnet[i]['pag_pos'] ← position(subnet[i]['pag']) ;
end
foreach subnet as i do
    subnet[i]['score'] ← (subnet[i]['deg_pos'] + subnet[i]['bet_pos'] + subnet[i]['clo_pos']) ;
end
ranked_subnet ← array_orderby(subnet, 'score', SORT_ASC, 'np', SORT_DESC) ; /* Sorts the subnetwork
   incrementally by the score and uses the largest NP as tie-breaking criterion */
foreach ranked_subnet as i ⇒ var do
    if (ranked_subnet[var]['np'] < NP) then
        unset(ranked_subnet[i]); /* Remove the researcher from the ranking */
    end
end
ranked_subnet ← array_slice(ranked_subnet, 0, NE);/* Limits the ranking by the given NE */
```

Figure 2: REALM analysis and ranking algorithm

The procedures described in 3.1 and 3.2 were performed with the aid of the Knime tool (knime.org). Knime was used to optimize the preprocessing of the large volume of text contained in the XML, JSON, and CSV data files, because it achieves almost 100% accuracy in the process of converting these data to RDF, also guaranteeing greater reliability in searches carried out on the database [8].

3.3 Academic impact analysis

This module is responsible for extracting productivity and academic impact metrics via SNA [4, 18, 20, 21, 37] of SCN built by the module described in 3.1. The metrics are extracted by way of an analysis and ranking algorithm that allows SCN mapping in three levels:

(i) Global - maps the SCN as a whole from the global graph, which allows comparing publication and collaboration behavior among researchers from different areas. To achieve this, the algorithm extracts bibliometric data from raw data retrieved from publications. It uses as parameters: number of researchers in the SCN, number of publications in the SCN, number of SCN components (subnets of connected nodes), sum of publications considering each researcher individually, sum of researchers considering each publication individually, average number of publications per researcher and average number of researchers per publication.

(ii) Local - maps the existing subnets, which helps to identify clusters of important researchers. For Local Analysis, a function was implemented in Javascript language that combines native resources of the language with functions made available by the library Cytoscape.js. Based on this function, it was possible to identify nodes, edges and connected components. The algorithm identifies the clusters of researchers, names the subnets according to the number of components (e.g. it assigns the id 'subnet 1' to the cluster with the highest number of researchers, 'subnet 2' to the second, and so on), and associates the researchers with their respective subnets. It uses as parameter the subnet's number of nodes/elements (NE).

(iii) Individual - maps the most influential researchers from the Number of Publications (NP) of a researcher and his network centrality, based on Degree, Betweenness, Closeness, and PageRank. These metrics were chosen by the definition of 'centrality' detailed in [6, 12, 36], where the authors mathematically demonstrate this concept to determine how central a vertex is in a graph, making it possible to assign scores to the vertices from these metrics.

For Individual Analysis, the analysis and ranking functions of REALM (Figure 2) have as input the researchers in their respective subnets (in case there are disconnected graphs) using as parameters the NP and the number of ordered elements (NE) ordered by the centrality metrics (these parameters are configurable). E.g. ordering only the 100 first-placed elements (NE = 100) in the four centrality metrics and that have 5 or more publications ($NP \geq 5$).

For the academic ranking, REALM calculates the centrality metrics Degree, Closeness and Betweenness of each researcher. This calculation is done by adapting the corresponding functions to each of these metrics, which are implemented in the Cytoscape.js library. Additionally, the PageRank values of each researcher are calculated as indicative of other important co-authorships [11].

```
SPARQL query prefixes based on the RDF data model

PREFIX ebucore: <https://www.ebu.ch/metadata/ontologies/ebucore/index.html#>
PREFIX schema: <http://schema.org/>
PREFIX realm: <https://realmproject.github.io/realm/datamodel#>
PREFIX dbo: <http://dbpedia.org/ontology/>
```

Query 1

```
SELECT DISTINCT ?news ?text ?CountFB
?CountGPlus
WHERE {?news a ebucore:NewsItem;
        schema:text ?text;
        realm:facebookCount ?CountFB;
        realm:gplusCount ?CountGPlus.
        FILTER (CONTAINS(str(?text),
        LCASE("Name")))}
```

Query 2

```
SELECT DISTINCT (COUNT(?news) as ?TotalNews)
(SUM(?CountFB) as ?TotalFB)
(SUM(?CountGPlus) as ?TotalGPlus)
WHERE {?news a ebucore:NewsItem;
        schema:text ?text;
        realm:facebookCount ?CountFB;
        realm:gplusCount ?CountGPlus.
        FILTER (CONTAINS(str(?text),
        LCASE("Name")))}
```

Query 3

```
SELECT DISTINCT (COUNT(?news) as ?n)
?country
WHERE {?news a ebucore:NewsItem;
        schema:text ?text;
        dbo:country ?country.
        FILTER (CONTAINS(str(?text),
        LCASE("Name")))}
GROUP BY (?country)
ORDER BY DESC(?n)
```

Figure 3: SPARQL queries that pull the altmetrics

3.4 Social impact analysis

This module is responsible for extracting social impact metrics, based on SPARQL queries performed on the triples database (built in the module of 3.2) from the system interface. The implementation consists of three SPARQL query groups (Figure 3) that run on the Apache Jena Fuseki triplestore through HTTP requests intermediated by the open source library EasyRDF. These queries are necessary for the extraction of altmetric indexes that can measure: (i) the reach of the researches in primary (online news) and secondary (e.g. scientific blogs and forums) communication vehicles (Query 1); (ii) its penetration in the population, via its dissemination on OSN such as Facebook and Google+ (Query 2); and (iii) its visibility at the global level, identifying the country of origin of the publication (Query 3). The queries use as parameters the number of mentions to a researcher in publications, the number of mentions in publications shared on OSN and number of mentions by country.

However, the name of a researcher can be cited in various ways on social media. Thus, a knowledge dataset on researchers and their variant names in academic publications should be used as data input. This dataset refers to a standardized text file separated by semicolons (CSV), where each researcher (tuple) has his own spellings/cells. The three queries use these spellings as a parameter, applying the || (OR) operator in the 'filter' clause along with the 'distinct' modifier to return, in a single query, the results of each researcher's spellings and ensure there are no repeated results.

Thereafter it is possible to create the altmetric ranking, based on the mentions and shares returned by the first two queries, and generate the map that shows the geographical distribution of the mentions based on the results of the third query. The altmetric ranking is acquired by means of the altmetric score, which is calculated by summing the results obtained in Query 2 using the formula (1):

$$scoreAlt = \left(n + \left(\frac{fb}{20} \right) + \left(\frac{gp}{20} \right) \right) \tag{1}$$

where 'n' is the number of mentions on news, blogs, and discussion forums, 'fb' is the number of shares on Facebook and 'gp' is the number of shares on Google+. The smaller weight for the OSN shares is based on a similar criterion used by altmetric.com [2].

As the queries are carried out, the social impact metrics are extracted and saved in the triplestore. From this point it's also possible to indicate in which category of reputation a researcher is, by correlating the academic impact versus social impact, whereby four impact categories are possible: (i) High academic and high social impact - outstanding researchers in the scenario. They are names of great influence in their field of work, belonging to networks of scientific collaboration with strong geopolitical/institutional references, and strong online presence. (ii) High Academic Impact - usually those are researchers that integrate well defined research nuclei, but with little online presence. (iii) High social impact - researchers that do not have a well-defined collaboration network, but often prefer other means of sharing their results, such as fast-tracks and scientific blogs, which makes their dissemination more practical and faster, especially on social media. (iv) Low academic and low social impact - Researchers of little importance in the scenario and little or no online presence.

Researcher reputation categories are graphically demonstrated by scatter plot diagrams implemented in Javascript using the Google Charts API. The variables academic index (normalization of the academic score) and social index (normalization of the altmetric score) are plotted against each other and, according to the normalized value of the scores, the researchers are plotted in the graph. Each quadrant of the diagram has a particular meaning, according to the categories that correlate the academic impact and social impact. For the diagram composed by the academic index on the X-axis and the social index on the Y-axis, the following interpretation of the graph can be performed: (i) Lower left quadrant - low academic impact and low social impact. (ii) Upper left quadrant - low academic impact and high social impact. (iii) Lower right quadrant - high academic impact and low social impact. (iv) Upper right quadrant - high academic impact and high social impact. For each researcher, the scores are normalized using the formula (2):

$$Z_i = \frac{x_i - min(x)}{max(x) - min(x)} \quad (2)$$

where x = $(x_1, ..., x_n)$ represents the set of values, Z_i is the normalized value of x_i in the ith iteration, min(x) is the smallest value in the set and max(x) is the largest value in the set.

3.5 Data storage

As the algorithms process the data of the modules 3.3 and 3.4, the information of academic and social impact is also triplified, according to the RDF data model (realm0.github.io/2), and stored persistently in the Apache Jena Fuseki triplestore. The triplification of these data is performed through updates on Jena, from SPARQL INSERT commands. The algorithm implemented for REALM dynamically creates each update, so that for each parameter received in an iteration, a set of triples is created for an INSERT request. The updates are sent to Jena via a connection intermediated by EasyRDF, through the 'update' parameter. Thereby, REALM allows the creation of sessions, which provide a way to save the calculated academic and social impact rankings. This also enables one to check the progress of a field or even make comparisons among different fields (e.g. how scientists collaborated to drive the major advances in Zika research and how the population reacted to the findings).

4 CASE STUDY: ZIKV

As stated in section 1, the framework's proposal is to serve as a new method for understanding the representativeness and recognition of researchers before society, based on altmetrics. Thus an implementation of the framework was tested in the Zika scenario, an emergency situation that provided a great wealth of data due to the recent outbreaks. Using REALM, we tried to answer two research questions: "who are the most influential scientists under the ACADEMIC perspective?" and "who are the most influential scientists under the SOCIAL perspective?" "ACADEMIC recognition" means the degree of reputation or fame of researchers for academic people. It takes into account the researcher's productivity and centrality (see section 3.3). "SOCIAL recognition" means the degree of reputation or fame of researchers for the lay public or non-academic people. It takes into account the visibility/reach of the researcher and its research in the population, and is measured via mentions on social media such as news sites, blogs, discussion forums and OSN (Facebook and Google+). At the end of our analysis, it was also verified, through correlation calculation, whether the fact that a researcher has a high academic reputation implies that he will have higher visibility on social media. The study is divided in six stages (explained below).

Collection of Zika publications in the indexing database PubMed and construction of the SCN - At this stage we used the PubMed query mechanism (https://www.ncbi.nlm.nih.gov/pubmed) to retrieve publications about the topic. This way, using as search string the term "Zika"[1] applied in the filters "title", "abstract" and "text" we retrieved data from 1,932 publications prior to 12/21/2016 in XML and CSV formats. From these data it was possible to build the Zika SCN, according to the operations described in 3.1, for later reading, visualization and extraction of academic impact metrics.

Collection and triplification of Zika publications on social media - At this stage the web crawler was set up to collect Zika publications (query "zika" OR "zyka" OR "zikv") on news sites, blogs and discussion forums, as well as shares on OSN such as Facebook, LinkedIn and Google+, in 115 languages, from December 2014 to December 2018 (1,491 days of collection). In this process the data of 1,351,284 publications on Zika were collected, triplified (as described in 3.2) and stored to compose a thematic database. After that, the system interface (available at: www.realm.net.br) was used to analyze the academic and social impacts. A brief tutorial on how REALM interface works is available at: https://youtu.be/NfcdG8o0PyE.

Reputation Analysis on the SCN – This step aims to answer the first question: "who are the most influential scientists under the ACADEMIC perspective?" To answer this question the built SCN was analyzed in three levels. At the first level, the global analysis was performed, where the network was verified as a whole.

At this point REALM mapped 6,808 researchers distributed among 83 components/clusters on the Zika SCN, where researchers on the subject published an average of 1.49 articles and the articles have an average of 5.20 researchers.

At the second level the local/group analysis was performed, where the subnets formed were verified to identify the most important groups of researchers. At this level of analysis the three most

[1]((zika[Title/Abstract]) AND zika[Text Word]) AND ("1500/01/01"[Date - Publication] : "2016/12/21"[Date - Publication])

Table 1: Color categories based on the productivity (NP)

Category	Condition	Category	Condition
Green	If NP ≥ 15	Purple	If NP ≥ 8 OR NP <10
Blue	If NP ≥ 10 OR NP <15	Red	If NP ≥ 5 OR NP <8

important clusters of researchers were identified. In this study they will be referred to as subnet 1 (208 nodes), subnet 2 (133 nodes) and subnet 3 (96 nodes).

In the third level, the individual analysis was performed, where the centrality metrics were applied to identify the most influential researchers within the three subnets. For the researchers reputation analysis in the academic scenario the following parameters were used: number of publications and centrality (Betweenness, Closeness, Degree and PageRank) of each researcher. The number of publications (productivity) is also an important criterion for determining whether a researcher is yielding progress in specific fields, such as Zika. That said, REALM was configured to take into account only researchers who published five or more times. In addition, four colour categories were assigned to the researchers, according to their productivity (as shown in Table 1).

After defining these criteria, it was observed that out of a total of 194 researchers who published 5 or more times, 8.3% belong to the green category, 10.8% belong to the blue category, 12.4% belong to the purple category and 68.5% belong to the red category. Next, the analysis was also configured so that only the 100 most influential researchers, according to the productivity/centrality criteria are displayed.

Once these criteria were defined, the most influential researchers were ranked by the algorithm (Figure 2) based on the Freeman metrics [12] (Betweenness, Closeness and Degree), from the sum of the positions, and individually on the PageRank metric. The last metric is used as a comparison criterion, since it indicates if a researcher is related to high centrality nodes.

After this procedure REALM ranked 110 names that can be considered the most academically influential on Zika research. These results are available at: http://bit.ly/2IINmlB. Table 2 shows, for each subnet, the top 10 researchers (most academically influential), according to the previously established criteria.

Social Repercussion Analysis - This step is related to the second question: "who are the most influential scientists under the SOCIAL perspective?" To adress this question, the three groups of queries (Figure 3) were executed on REALM, extracting altmetric indexes from: (i) communication vehicles, to verify if they are reporting the advances and discoveries of a researcher regarding ZIKV - for this, REALM uses the total of mentions (on news sites, forums and blogs) to a researcher. (ii) OSN, to assess the dissemination and reach of publications in the population - for this, REALM analyzes the propagation of the publication about a researcher and his discoveries from mentions on Facebook and Google+. (iii) Country mentions – to provide a geographic perspective of these research impacts. For this, REALM analyzes the total mentions by country. The three queries are central to this study, since the first one captures the online attention by major media (news sites) and by secondary ones (blogs and scientific forums, for example), that is, if they are reporting the advances and discoveries made by the

Table 2: Most influential researchers on subnets 1, 2 and 3 under the academic perspective

#	RESEARCHER	NP	BET/P	CLO/P	DEG/P	S	PR/P
	Subnet 1						
1	QIN CF	15	0.466/3	0.998/1	26/2	6	0.0037/7
2	WEAVER SC	17	0.279/7	0.943/2	27/1	10	0.0030/9
3	VASILAKIS N	16	0.276/8	0.917/3	22/3	14	0.0024/13
4	SHI PY	12	1.0/1	0.903/4	12/12	17	0.0050/3
5	LIU X	5	0.290/6	0.859/7	19/5	18	0.0003/157
6	KO AI	10	0.505/2	0.817/10	13/11	23	0.0003/157
7	DENG YQ	10	0.157/13	0.901/5	17/7	25	0.0023/15
8	ZHAO H	5	0.458/4	0.807/12	13/11	27	0.0032/8
9	GAO GF	7	0.416/5	0.797/13	10/14	32	0.0015/34
10	RIBEIRO GS	7	0.184/11	0.786/14	12/12	37	0.0047/5
	Subnet 2						
#	RESEARCHER	NP	BET/P	CLO/P	DEG/P	S	PR/P
1	JAMIESON DJ	21	0.113/4	1.0/1	41/1	6	0.0114/1
2	ODUYEBO T	13	0.190/1	0.956/3	37/2	6	0.0013/30
3	POWERS AM	13	0.117/3	0.911/4	29/3	10	0.0054/3
4	HONEIN MA	19	0.079/7	0.975/2	37/2	11	0.0019/15
5	MEANEY DELMAN	13	0.112/5	0.891/5	28/4	14	0.0006/61
6	FISCHER M	18	0.094/6	0.883/6	29/3	15	0.0005/80
7	RIVERA GARCIA B	11	0.141/2	0.829/10	26/5	17	0.0014/27
8	PETERSEN EE	13	0.034/14	0.880/7	29/3	24	0.0015/25
9	MUNOZ JORDAN J	8	0.048/10	0.788/13	23/7	30	0.0021/12
10	HILLS SL	7	0.043/11	0.793/12	18/10	33	0.0007/54
	Subnet 3						
#	RESEARCHER	NP	BET/P	CLO/P	DEG/P	S	PR/P
1	CAO LORMEAU VM	16	0.119/2	0.663/1	25/1	4	0.0007/35
2	MUSSO D	33	0.062/5	0.629/2	22/2	9	0.0073/2
3	LEPARC GOFFART I	21	0.112/3	0.582/4	21/3	10	0.0005/46
4	MALLET HP	8	0.145/1	0.601/3	13/6	10	0.0017/13
5	SIMON LORIERE E	5	0.021/7	0.554/6	21/3	16	0.0005/52
6	DESPRES P	7	0.069/4	0.547/8	15/5	17	0.0016/15
7	SAKUNTABHAI A	5	0.016/9	0.548/7	20/4	20	0.0043/4
8	TEISSIER A	8	0.011/11	0.555/5	10/7	23	0.0003/72
9	ROCHE C	6	0.005/13	0.536/9	7/10	32	0.0008/29
10	GAREL C	5	0.003/14	0.487/12	9/8	34	0.0010/23

Table Acronyms: BET/P = Betweenness/Position. CLO/P = Closeness/Position. DEG/P = Degree/Position. S = Score. PR/P = PageRank/Position. In case of tie consider: 1st - number of publications; 2nd - higher Degree.

scientist concerning the disease; the second query complements the first one, since it indicates that these news are spreading through the OSN and reaching a wider audience, as well as providing a method to trace outstanding research; and the third query highlights the public engagement and the visibility at global level.

However, the citation name extracted from PubMed is obviously insufficient to identify a researcher's citation records. Thus, we identified alternative spellings to build the spellings dataset (explained in 3.4). This task was performed via Knime, combining pieces of information about the authors extracted from the XML and CSV, such as LastName, ForeName, Initials, E-mail, ORCID, Affiliations and co-authorships.

By way of example, we have Xavier de Lamballerie (DE LAMBALLERIE X), a leading virologist, Professor at Inserm, IRD, Aix-Marseille University and coordinator of the international consortium ZIKAlliance [40]. For this researcher, disregarding inconsistent spellings (e.g. 'de X Lamballerie' or 'de Xavier Lamballerie') there are a few possible name combinations. Thus we filtered these names by querying them together on REALM's "Plain Search" functionality (available at: www.realm.net.br/impacto_social_grafias.php) and removing the names that did not match any results. Only three

Table 3: Most influential researchers under the social perspective

#	RESEARCHER	SMM	SFB	SG+	ALTS	COUNTRY	#	RESEARCHER	SMM	SFB	SG+	ALTS	COUNTRY
1	DIAMOND MS	2261	66786	167	5608.65	USA	16	SHARP TM	493	3158	56	653.7	USA
2	PETERSEN LR	2605	44851	125	4853.8	USA	17	MOORE CA	475	3322	24	642.3	USA
3	JAMIESON DJ	2134	6911	8376	2898.35	USA	18	VENTURA CV	265	7382	11	634.65	Brazil
4	VAN DER LINDEN V	1755	19332	131	2728.15	Brazil	19	SHI PY	206	7836	6	598.1	USA
5	HONEIN MA	2148	5900	49	2445.45	USA	20	FISCHER M	457	2536	63	586.95	USA
6	WEAVER SC	1327	6544	107	1659.55	USA	21	CAMPOS GS	477	1223	4	538.35	Brazil
7	KO AI	1340	3766	53	1530.95	USA	22	VENTURA LO	242	5316	20	508.8	Brazil
8	STAPLES JE	1346	3213	24	1507.85	USA	23	BANDEIRA AC	430	1489	6	504.75	Brazil
9	MARTELLI CM	588	17013	26	1439.95	Brazil	24	BELFORT R JR	443	1092	7	497.95	Brazil
10	SONG H	949	8889	47	1395.8	USA	25	MUSSO D	419	152	5	426.85	French Poly
11	RASMUSSEN SA	1160	3861	22	1354.15	USA	26	BROOKS JT	388	517	12	414.45	USA
12	TESH RB	435	7128	4250	1003.9	USA	27	ROSSI SL	350	1131	27	407.9	USA
13	QIN CF	322	11583	2	901.25	China	28	MEAD P	258	1002	0	308.1	USA
14	RODRIGUES LC	579	3417	40	751.85	Brazil	29	PETERSEN EE	250	1151	5	307.8	USA
15	MINER JJ	367	7023	31	719.7	USA	30	LANCIOTTI RS	279	529	8	305.85	USA

Table acronyms: SSM = Social Media Mentions. SFB = Shares on Facebook. SG+ = Shares on Google+. ALTS = Altmetric Score

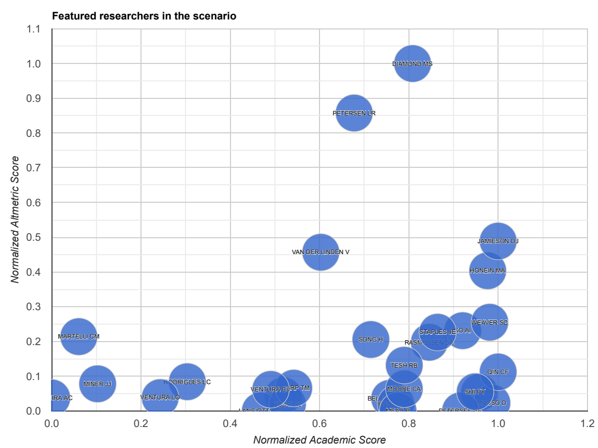

Figure 4: Featured researchers - Scatter Plot

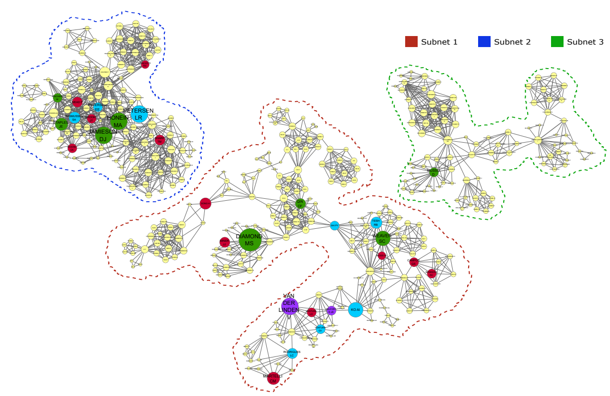

Figure 5: Featured researchers – Co-authorship network

spellings returned results: 'de Lamballerie X', 'Xavier de Lamballerie' and 'X. de Lamballerie'. Hence, this filter was applied on all the influential researchers identified in the academic impact module and these spellings were added to the spellings dataset. From it, REALM ordered 110 researchers according to their social recognition, that is, according to their altmetric score (Formula 1). These results are available at: http://bit.ly/2R3uaCO. Finally, it was possible to see who are the featured names on Zika research through REALM's respective functionality, which displays, in the shape of a scatterplot, the featured names in the scenario (as detailed in 3.4). We configured REALM to display the 30 top researchers in this sense, available at: http://bit.ly/2EZnrVy. Last but not least, another important contribution on the social impact analysis performed in this study is the possibility to see these researchers' most important findings, which were widely shared on social media, available at: http://bit.ly/2WEpd9D.

Table 3 shows the altmetric ranking of the 30 most influential scientists under the social perspective. Figure 4 shows the respective scatter plot. Figure 5 shows the Zika SCN, where one can observe the top 30 outstanding names in the scenario, according to the color categories defined in Table 1 and the size of the node varying according to the importance of the researcher.

Identification of featured research in Zika - After identifying the most visible researchers on social media, the next step was to investigate a little more deeply about who they are, what types of research they work on and what discoveries they have made recently. For this purpose, we observed the 'Details' tab of the researcher in the system, which in turn was implemented in order to return the researches that were most reported/shared on social media, which certainly denounce that something important was discovered by the researcher. In order to analyze the altmetric criteria and the created ranking, we compared our results with those of Altmetric.com using the altmetric bookmarklet extension (altmetric.com/products/free-tools/bookmarklet), which verifies how much a publication is quoted on social media and assigns it a score based on article-level metrics [1, 34]. As the focus of this study is to verify metrics at the researcher level, this tool provides a good comparison baseline regarding the performance of papers related to the most important research - identified by means of the method developed in this study - of the featured profiles that reached high impact on social media. With this in mind, the following paragraphs detail the six most cited and shared researchers on OSN based on the results returned by these researchers Details tab.

Michael S. Diamond (DIAMOND MS) is an american professor of medicine at the Washington University School of Medicine where he is also the associate director at the Center for Human Immunology and Immunotherapy Programs. Diamond published 16 times on Zika, being cited 2,261 times on the triples database, where publicatons that cited it had a reach of 66,786 shares on Facebook and 167 on Google+. He is senior co-author of a study published in the journal Nature [33] which describes the discovery of a natural antibody called ZIKV-117 that can protect both the fetus and people already infected by Zika. This research is an important step in creating a vaccine against the virus[2]. This study hit the 720-point mark on altmetric.com score[3]. Diamond is also co-author of a research published in the Journal of Experimental Medicine [39] which shows that the ZIKV was used to treat glioblastoma (aggressive brain cancer). Results showed that by directly applying ZIKV to the tumor, the virus was able to infect and kill only cancer cells in brains of adult mice[4].

Lyle R. Petersen (PETERSEN LR) is the director of the Division of Vector-Borne Diseases (DVBD) in the National Center for Emerging and Zoonotic Infectious Diseases (NCEZID) at the Centers for Disease Control and Prevention (CDC). Petersen has 10 academic publications, was mentioned in 2,605 news stories and shared on Facebook 44,851 times and on Google+ 125 times. He has a strong presence on social media, publishing several bulletins and reports in the Morbidity and Mortality Weekly Report[5] (MMWR), which is the CDC's main vehicle for publishing scientific information and public health recommendations for the United States. These reports are the basis for sundry publications on traditional news sites such as CNN[6], CBN News[7], Washington Post[8], NBC News[9], The New York Times[10], Fox News[11], among others, which causes great social outreach. His academic publications are related to the public health of the United States, to the prevention and control of vector-borne diseases, such as the ZIKV [7, 26]. The report on the topic published in the MMWR reached 1,287 points on the altmetric.com score[12].

Denise J. Jamieson (JAMIESON DJ) is an American, captain in the American Public Health Service and serves as head of the Department of Health and Fertility at CDC, and is an adjunct professor in the Department of Gynecology and Obstetrics at Emory University in Atlanta. Jamieson published 21 times on Zika, being cited 2,134 times on the triples database, where the news that cited her had a reach of 6,911 shares on Facebook and 8,376 on Google+. She and Dr. Honein MA (detailed below) conducted a long-term study [17], that verified birth defects related to the ZIKV, where it was found that the virus may continue to replicate in the brains of infants after birth and it can also persist in the mother's placenta for months[13]. This study hit the 299-point mark on the altmetric.com score[14].

[2]http://www.medicalnewstoday.com/articles/313935.php
[3]https://www.altmetric.com/details/13413916?src=bookmarklet
[4]https://www.bbc.com/news/health-41146628
[5]http://bit.ly/2L6EkzQ
[6]https://cnn.it/2I7HTpm
[7]https://cbsn.ws/2XA3mwk
[8]https://wapo.st/2IBm7JE and https://wapo.st/2WuNui6
[9]https://nbcnews.to/2KCRaXR
[10]https://nyti.ms/2Itr86M and https://nyti.ms/2KCRNko
[11]https://fxn.ws/2K9wkzR
[12]https://www.altmetric.com/details/40416293?src=bookmarklet
[13]https://nbcnews.to/2I7FoTX
[14]https://www.altmetric.com/details/14720317?src=bookmarklet

Vanessa Van Der Linden (VAN DER LINDEN V) is a Brazilian physiatrist responsible for clinical care at the Association for Assistance to the Disabled Child (AACD) in Recife and who works as a pediatric neurologist at Oswaldo Cruz University Hospital. Linden published 8 times on the Zika disease, being cited 1,755 times on the triples database, where the news that cited her had a reach of 19,332 shares on Facebook and 131 on Google+. Dr. Linden was the first to note the relationship between Zika and microcephaly[15], and was awarded the "Leadership for the Americas" award for her findings on the disease[16]. In her recent study [35], she and her team observed the development of 13 infants infected by Zika before birth and found that Congenital Zika Syndrome (CZS) does not necessarily cause prenatal microcephaly. Babies with normal head circumference may have brain problems and other abnormalities associated with CZS and may develop microcephaly after birth, which highlights the importance of ultrasonography and prenatal monitoring for cases of pregnancy where there is exposure to the virus[17]. This study hit the 503-point mark on the altmetric.com score[18].

Margaret Honein (HONEIN MA) is an American epidemiologist who serves as a consultant and senior scientist at the CDC, where she is currently head of the congenital defects sector. She belongs to the same research group as Denise J. Jamieson. Honein published 19 times on the Zika disease, being cited 2,148 times in news on the triples database, where the news that cited her had a reach of 5,900 shares on Facebook and 49 on Google+. She conducted a study [16] where, in a sample of 442 completed pregnancies, 6% of them had evidence of birth defects related to the ZIKV, most of them being microcephaly or abnormalities in the brain. Chances are almost double (11%) for women infected with the virus in the first trimester of pregnancy[19]. This study hit the 1,266-point mark on the altmetric.com score[20].

Another Brazilian who featured prominently for her research related to ZIKV was Celina Maria Turchi Martelli, (MARTELLI CM). She is a visiting researcher at the Oswaldo Cruz Foundation (Fiocruz), where she also works as a researcher at the Aggeu Magalhães Research Center, and is an emeritus professor at the Federal University of Goiás. Martelli published 5 times on Zika disease, being cited 588 times on the triples database, where the news that cited her had a reach of 17,013 shares on Facebook and 26 on Google+. She was chosen by the journal Nature[21] as one of the top 10 names of science in the year 2016. Martelli stood out worldwide because she leads the research group that officially published [3] for the first time the correlation between Zika in women and cases of microcephaly in infants[22]. This study reached the mark of 581 points on the altmetric.com score[23].

Statistical correlations – Having analyzed the academic and social impact we verified if a highly academically influential researcher will therefore have a high social repercussion. To achieve

[15]http://bit.ly/2WYdXE7 and https://bbc.in/2IzWSHD
[16]http://www.thedialogue.org/event/gala2016/
[17]https://nbcnews.to/2R08lUn
[18]https://www.altmetric.com/details/13896288?src=bookmarklet
[19]https://nbcnews.to/2I7FoTX
[20]https://www.altmetric.com/details/14720110?src=bookmarklet
[21]http://www.nature.com/news/nature-s-10-1.21157
[22]https://glo.bo/2K68Dsv
[23]https://www.altmetric.com/details/12026883?src=bookmarklet

Table 4: Statistical correlations between academic and social impact on subnets 1, 2 e 3

	Subnet 1						Subnet 2						Subnet 3				
	MSM	**BET**	**CLO**	**DEG**	**PR**		**MSM**	**BET**	**CLO**	**DEG**	**PR**		**MSM**	**BET**	**CLO**	**DEG**	**PR**
MSM	1	0.1928	0.0688	0.0128	0.2293	**MSM**	1	0.4165	0.4290	0.3487	0.0387	**MSM**	1	0.2312	0.3355	0.2902	0.0351
BET	0.1928	1	0.5687	0.6908	0.2329	**BET**	0.4165	1	0.7408	0.7424	0.2191	**BET**	0.2312	1	0.8328	0.7993	0.4336
CLO	0.0688	0.5687	1	0.5041	0.0750	**CLO**	0.4290	0.7408	1	0.9060	0.1395	**CLO**	0.3355	0.8328	1	0.9152	0.4016
DEG	0.0128	0.6908	0.5041	1	0.1871	**DEG**	0.3487	0.7424	0.9060	1	0.2835	**DEG**	0.2902	0.7993	0.9152	1	0.4319
PR	0.2293	0.2329	0.0750	0.1871	1	**PR**	0.0387	0.2191	0.1395	0.2835	1	**PR**	0.0351	0.4336	0.4016	0.4319	1

this, we verified the correlation between the reputation of a researcher in society and the reputation of a researcher in the SCN using correlation calculation. Given the non-normality of the data, Spearman's nonparametric correlation test was used. The test correlated the variables Betweenness (BET), Closeness (CLO), Degree (DEG), PageRank (PR) and Mentions on Social Media (MSM) and the results can vary between -1 and 1. If the result is closer to -1 or 1 the variables are strongly correlated (if close to 1, the correlation is direct, if close to -1, the correlation is inverse). If the result is tending to 0 (middle of the interval) the correlation is weak [32].

Observing the matrices of Table 4, it is verified that the weaker correlations occurred between Freeman's centrality metrics and social media citations, in subnet 1, and between PageRank and social media citations in subnets 2 and 3. At this point, we noted that the very low values of Degree, Betweenness and Closeness, to a certain extent, may have influenced in the weak correlation, since some of these researchers may have a high number of mentions. The lowest values in Table 4 occur with the correlation between PageRank and the other metrics. Our results for the Zika case study are different when compared to the correlations of the study by [37], who studied the correlations of centrality metrics and academic citations in the domain of Library and Information Sciences, where the lowest correlations occurred with Closeness data. All metrics had positive correlations with social media citations. The centrality metric that most correlated with the social media citations in subnet 1 is PageRank and in subnets 2 and 3 is Closeness. These values indicate that the best positioned in PageRank and Closeness were highlighted in the citation count. However, according to [32], such values could be interpreted as a moderate to weak correlation. That is, the fact that a researcher is academically recognized does not always lead him to be socially recognized and vice versa.

5 CONCLUSIONS

In this work we presented the computational framework REALM, which provides a set of metrics to assess the reputation of researchers as well as mechanisms for measuring and visualizing the impacts of science on specific research scenarios, in this case, on Zika research. The extraction of three groups of metrics from a single tool represents a step forward in measuring the impacts of science, since productivity, academic influence and social impact metrics alone may not be sufficient to provide more accurate insights into the academic use of social media.

The high number of shares in some cases indicates that the research had great impact on OSN (penetration in the population). These cases refer to publications reporting progress in studies related to ZIKV and other important scientific discoveries, such as new treatments and the proximity of a cure. Researchers with higher social impact are members of international networks, usually belonging to well-known research institutions from developed countries (Centers for Disease Control and Prevention/CDC, Washington University School of Medicine, Oswaldo Cruz Foundation/Fiocruz, Emory University, among others), with financial support to their research, and high productivity. Their advances and discoveries are followed by social media, and usually have a direct social impact, fighting against or controlling the disease. Their research are applied to three different areas: vaccine, drugs and diagnostic tools development (innovative research), the emergence of the disease in their countries, especially in Brazil, (epidemiological research) and virus study (virological research). These achievements can be confirmed by checking these researchers most important findings, which are available at: http://bit.ly/2WEpd9D.

In addition to the framework's implementation itself, this study provides a contribution to the research scenario on Zika, since to date there are no co-authorship mapping on the disease at the micro/individual level, that is, analyzing in depth the scientific interactions on the subject. Besides, REALM can aid researchers, universities or even funding agencies to better visualize and study these issues. The system was designed in a way that eases in the tasks of finding specialists in specific domains, collect bibliographic material, improve the scientific disclosure, recommendation for team formation, among other features. As future work, it is intended to analyze research impacts in other scenarios such as Chikungunya and Dengue, and in other domains (i.e. Computer Science). It is also intended to investigate the engagement with the public, that is, how many people and what kind of audience reads and publishes on these topics.

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