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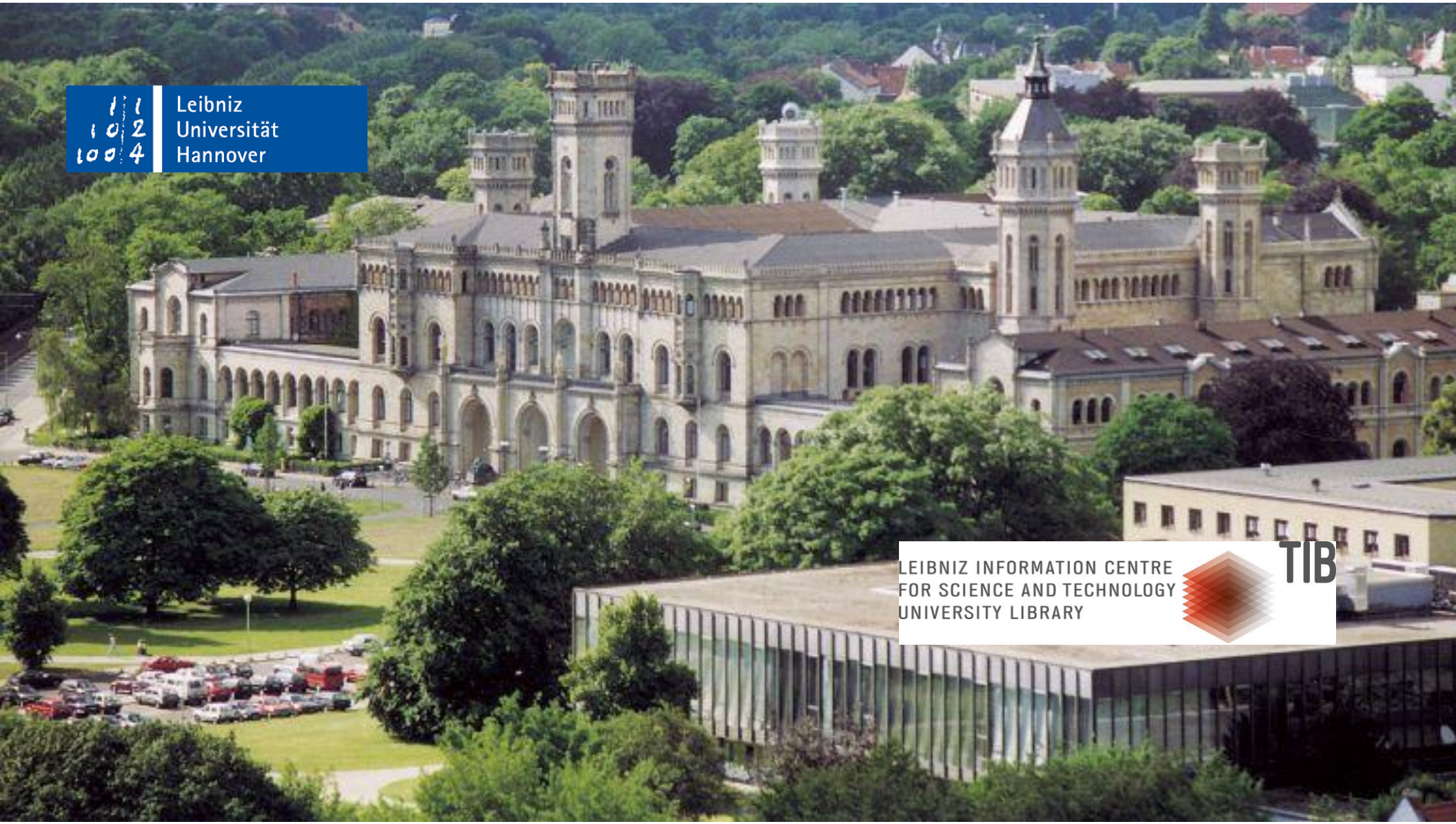
From papers to knowledge: Representing scientific contributions in the Open Research Knowledge Graph

Prof. Dr. Sören Auer
Leibniz University of Hannover
TIB Technische Informationsbibliothek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Gottfried Wilhelm Leibniz
* 21. Juni/ 1. Juli 1646 in Leipzig
À 14. November 1716 in Hannover

Leibniz Universität Hannover

Namesake

Namesake

Leibniz Association

Library of

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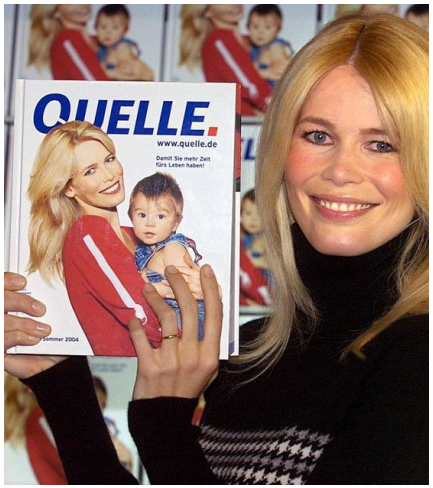
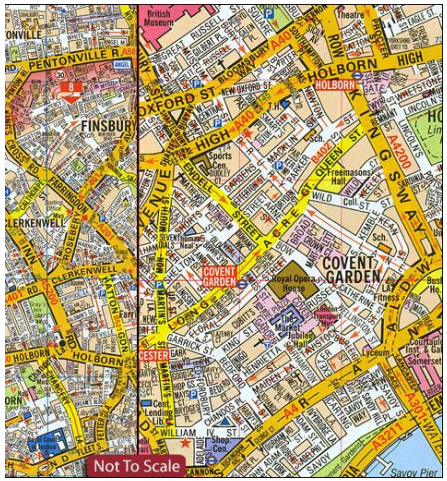
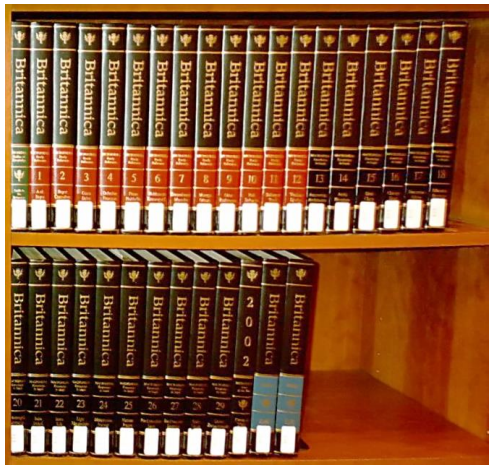
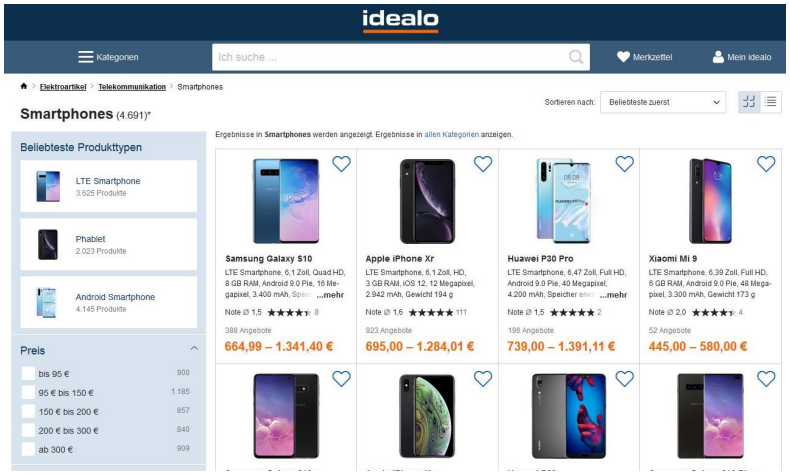
How did information flows change in the digital era?

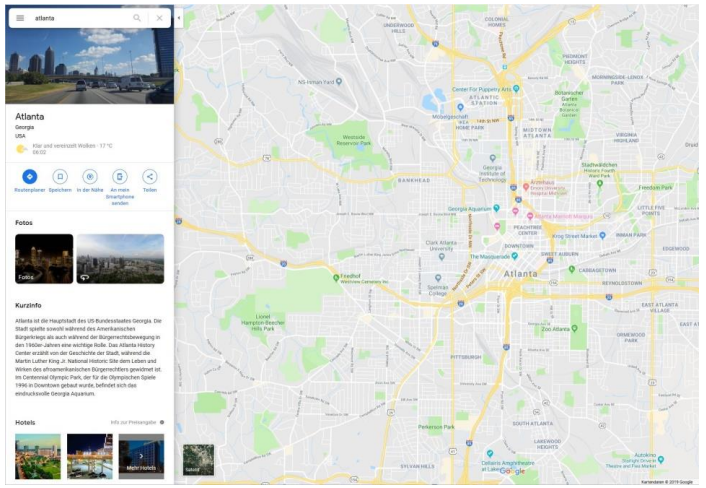


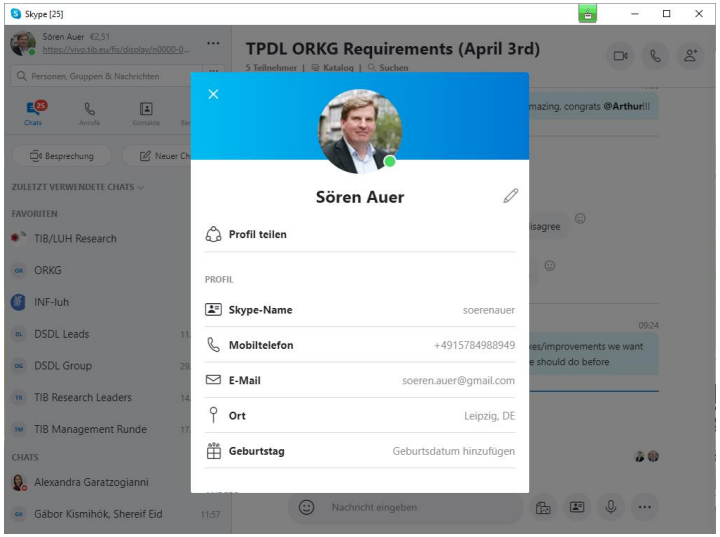




How does it work today?







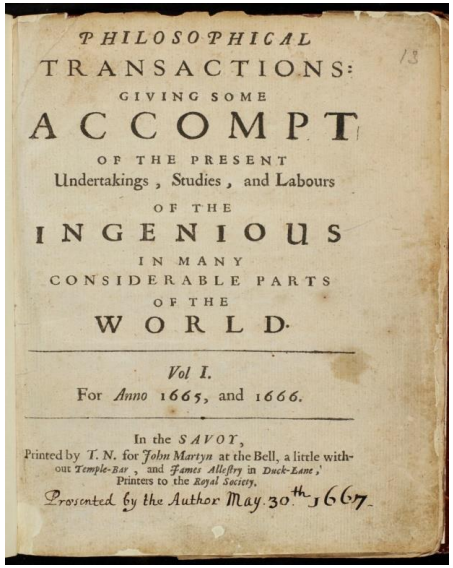
The World of Publishing & Communication has profundely changed

- **New means adapted to the new possibilities** were developed, e.g. „zooming", dynamics
- **Business models** changed completely
- More focus on data, interlinking of **data / services and search** in the data
- Integration, **crowdsourcing, data curation** play an important role

What about Scholarly Communication?

Scholarly Communication has not changed (much)

17th century

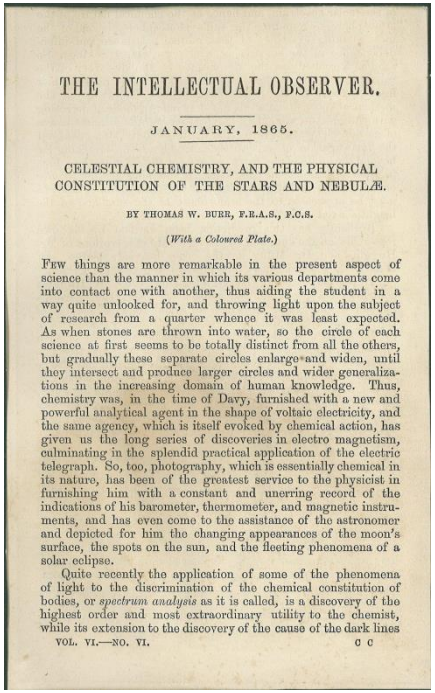


PHILOSOPHICAL
TRANSACTIONS:
GIVING SOME
ACCOMPT
OF THE PRESENT
Undertakings, Studies, and Labours
OF THE
INGENIOUS
IN MANY
CONSIDERABLE PARTS
OF THE
WORLD.

Vol I.
For Anno 1665, and 1666.

In the SAVOY,
Printed by T. N. for John Martyn at the Bell, a little without Temple-Bar, and James Allestry in Duck-Lane, Printers to the Royal Society.
Presented by the Author May 30th 1667

19th century



THE INTELLECTUAL OBSERVER.

JANUARY, 1865.

CELESTIAL CHEMISTRY, AND THE PHYSICAL CONSTITUTION OF THE STARS AND NEBULÆ.

BY THOMAS W. BURR, F.R.A.S., F.C.S.

(*With a Coloured Plate.*)

Few things are more remarkable in the present aspect of science than the manner in which its various departments come into contact one with another, thus aiding the student in a way quite unlooked for, and throwing light upon the subject of research from a quarter whence it was least expected. As when stones are thrown into water, so the circle of each science at first seems to be totally distinct from all the others, but gradually these separate circles enlarge and widen, until they intersect and produce larger circles and wider generalizations in the increasing domain of human knowledge. Thus, chemistry was, in the time of Davy, furnished with a new and powerful analytical agent in the shape of voltaic electricity, and the same agency, which is itself evoked by chemical action, has given us the long series of discoveries in electro magnetism, culminating in the splendid practical application of the electric telegraph. So, too, photography, which is essentially chemical in its nature, has been of the greatest service to the physicist in furnishing him with a constant and unerring record of the indications of his barometer, thermometer, and magnetic instruments, and has even come to the assistance of the astronomer and depicted for him the changing appearances of the moon's surface, the spots on the sun, and the fleeting phenomena of a solar eclipse.

Quite recently the application of some of the phenomena of light to the discrimination of the chemical constitution of bodies, or *spectrum analysis* as it is called, is a discovery of the highest order and most extraordinary utility to the chemist, while its extension to the discovery of the cause of the dark lines

20th century

A Relational Model of Data for Large Shared Data Banks

E. F. CODD
IBM Research Laboratory, San Jose, California

Future users of large data banks must be protected from having to know how the data is organized in the machine (the internal representation). A prompting service which supplies such information is not a satisfactory solution. Activities of users at terminals and most application programs should remain unaffected when the internal representation of data is changed and even when some aspects of the external representation are changed. Changes in data representation will often be needed as a result of changes in query, update, and report traffic and natural growth in the types of stored information.

Existing noninferential, formatted data systems provide users with tree-structured files or slightly more general network models of the data. In Section 1, inadequacies of these models are discussed. A model based on *n*-ary relations, a normal form for data base relations, and the concept of a universal data sublanguage are introduced. In Section 2, certain operations on relations (other than logical inference) are discussed and applied to the problems of redundancy and consistency in the user's model.

KEY WORDS AND PHRASES: data bank, data base, data structure, data organization, hierarchies of data, networks of data, relations, derivability, redundancy, consistency, composition, join, retrieval language, predicate calculus, security, data integrity
CR CATEGORIES: 3.70, 3.73, 3.75, 4.20, 4.22, 4.29

1. Relational Model and Normal Form

1.1. Introduction

This paper is concerned with the application of elementary relation theory to systems which provide shared access to large banks of formatted data. Except for a paper by Childs [1], the principal application of relations to data

The relational view (or model) of data described in Section 1 appears to be superior in several respects to the graph or network model [3, 4] presently in vogue for noninferential systems. It provides a means of describing data with its natural structure only—that is, without superimposing any additional structure for machine representation purposes. Accordingly, it provides a basis for a high level data language which will yield maximal independence between programs on the one hand and machine representation and organization of data on the other.

A further advantage of the relational view is that it forms a sound basis for treating derivability, redundancy, and consistency of relations—these are discussed in Section 2. The network model, on the other hand, has spawned a number of confusions, not the least of which is mistaking the derivation of connections for the derivation of relations (see remarks in Section 2 on the "connection trap").

Finally, the relational view permits a clearer evaluation of the scope and logical limitations of present formatted data systems, and also the relative merits (from a logical standpoint) of competing representations of data within a single system. Examples of this clearer perspective are cited in various parts of this paper. Implementations of systems to support the relational model are not discussed.

1.2. Data Dependencies in Present Systems

The provision of data description tables in recently developed information systems represents a major advance toward the goal of data independence [5, 6, 7]. Such tables facilitate changing certain characteristics of the data representation stored in a data bank. However, the variety of data representation characteristics which can be changed *without logically impairing some application programs* is still quite limited. Further, the model of data with which users interact is still cluttered with representational properties, particularly in regard to the representation of collections of data (as opposed to individual items). Three of the principal kinds of data dependencies which still need to be removed are: ordering dependence, indexing dependence, and access path dependence. In some systems these dependencies are not clearly separable from one another.

1.2.1. *Ordering Dependence.* Elements of data in a data bank may be stored in a variety of ways, some involving no concern for ordering, some permitting each element to participate in one ordering only, others permitting each

21th century

AGDISTIS - Graph-Based Disambiguation of Named Entities using Linked Data

Ricardo Usbeck[1,2], Axel-Cyrille Ngonga Ngomo[1], Michael Röder[1,2], Daniel Gerber[1], Sandro Athaide Coelho[3], Sören Auer[4], and Andreas Both[2]

[1] University of Leipzig, Germany , [2] R&D, Unister GmbH, Germany, [3] Federal University of Juiz de Fora, Brazil, [4] University of Bonn & Fraunhofer IAIS, Germany
email: {usbeck|ngonga}@informatik.uni-leipzig.de

Abstract. Over the last decades, several billion Web pages have been made available on the Web. The ongoing transition from the current Web of unstructured data to the Web of Data yet requires scalable and accurate approaches for the extraction of structured data in RDF (Resource Description Framework) from these websites. One of the key steps towards extracting RDF from text is the disambiguation of named entities. While several approaches aim to tackle this problem, they still achieve poor accuracy. We address this drawback by presenting AGDISTIS, a novel knowledge-base-agnostic approach for named entity disambiguation. Our approach combines the Hypertext-Induced Topic Search (HITS) algorithm with label expansion strategies and string similarity measures. Based on this combination, AGDISTIS can efficiently detect the correct URIs for a given set of named entities within an input text. We evaluate our approach on eight different datasets against state-of-the-art named entity disambiguation frameworks. Our results indicate that we outperform the state-of-the-art approach by up to 29% F-measure.

1 Introduction

The vision behind the Web of Data is to provide a new machine-readable layer to the Web where the content of Web pages is annotated with structured data (e.g., RDFa [1]). However, the Web in its current form is made up of at least 15 billion Web pages.[1] Most of these websites are unstructured in nature. Realizing the vision of a usable and up-to-date Web of Data thus requires scalable and accurate natural-language-processing approaches that allow extracting RDF from such unstructured data. Three tasks play a central role when extracting RDF from unstructured data: named entity recognition (NER), named entity disambiguation (NED), also known as entity linking [16], and relation extraction (RE). For the first sentence of Example 1, an accurate named entity recognition approach would return the strings `Barack Obama` and `Washington, D.C.`. A high-quality DBpedia-based named entity disambiguation (NED) approach would use these already recognized named entities and map the strings

[1] Data gathered from `http://www.worldwidewebsize.com/` on January 4th, 2014.

Meanwhile other information intense domains were completely disrupted: mail order catalogs, street maps, phone books, é

We need to rethink the way how research is represented and communicated

Challenges we are facing:

Digitalisation of Science	Monopolisation by commercial actors	Reproducibility Crisis	Proliferation of publications	Deficiency of Peer Review
▪ Data integration and analysis ▪ Digital collaboration	▪ Publisher look-in effects ▪ Maximization of profits [1]	▪ Majority of experiments are hard or not reproducible [2]	▪ Publication output doubled within a decade ▪ continues to rise [3]	▪ Deteriorating quality [4] ▪ Predatory publishing

[1] http://thecostofknowledge.com, https://www.projekt-deal.de
[2] M. Baker: *1,500 scientists lift the lid on reproducibility*, *Nature*, 2016.
[3] *Science and Engineering Publication Output Trends*, National Science Foundation, 2018.
[4] J. Couzin-Frankel: *Secretive and Subjective, Peer Review Proves Resistant to Study.* Science, 2013.

Proliferation of scientific literature

Science and engineering articles by region, country: 2004 and 2014

Rank	Region, country, or economy	2004	2014	Average annual growth rate (%)	2014 world total (%)	2014 cumulative world total (%)
na	World	1,272,362	2,290,294	6.1	100.0	na
1	United States	336,194	431,623	2.5	18.8	18.8
2	China	110,388	395,588	13.6	17.3	36.1
3	Germany	72,177	107,747	4.1	4.7	40.8
4	India	28,752	106,574	14.0	4.7	45.5
5	Japan	95,999	103,793	0.8	4.5	50.0
6	United Kingdom	75,119	101,536	3.1	4.4	54.4
7	France	53,375	74,269	3.4	3.2	57.7
8	Italy	42,647	70,453	5.1	3.1	60.8
9	South Korea	27,029	63,748	9.0	2.8	63.5
10	Canada	40,624	60,916	4.1	2.7	66.2
11	Spain	30,977	56,604	6.2	2.5	68.7
12	Brazil	18,814	53,152	10.9	2.3	71.0
13	Australia	26,277	52,269	7.1	2.3	73.3
14	Russia	26,869	43,487	4.9	1.9	75.2
15	Iran	4,952	36,539	22.1	1.6	76.8

Source: National Science Foundation: Science and Engineering Publication Output Trends: https://www.nsf.gov/statistics/2018/nsf18300/nsf18300.pdf

Reproducibility Crisis

1,500 scientists lift the lid on reproducibility
Monya Baker in *Nature,* 2016. **533** (7604): 452ï 454. doi:10.1038/533452a:

- 70% failed to reproduce at least one other scientist's experiment
- 50% failed to reproduce one of their own experiments

Failure to reproduce results among disciplines
(in brackets own results)

chemistry	87%	(64%)
biology	77%	(60%)
physics and engineering	69%	(51%)
Earth sciences	64%	(41%)

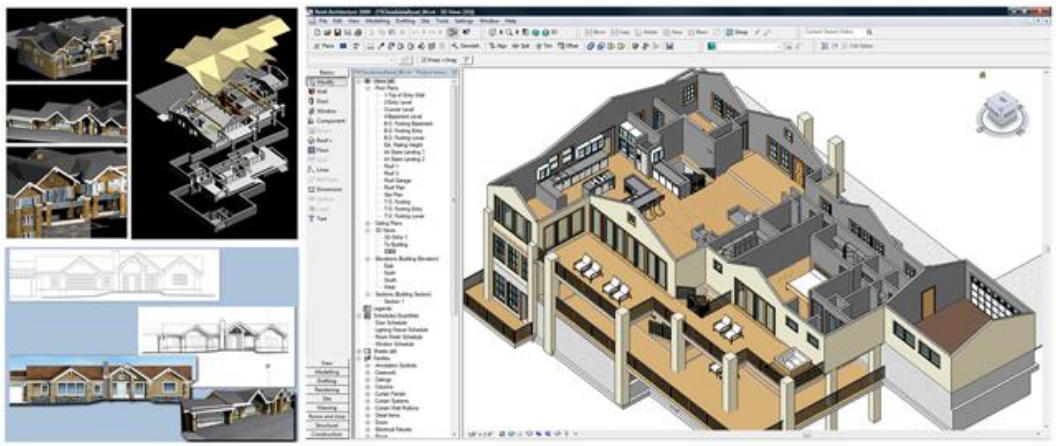
Source: © Stanford Medicine - Stanford University

Duplication and Inefficiency

How can we avoid duplication if the terminology, research problems, approaches, methods, characteristics, evaluations, é are not properly defined and identified?

How would you build an engine / building without properly defining their parts, relationships, materials, characteristics é ?

Source: https://thumbs.worthpoint.com/zoom/images2/1/0316/22/revell-4-visible-8-engine-plastic_1_d2162f52c3fa3a6f72d2722f6c50b7b2.jpg



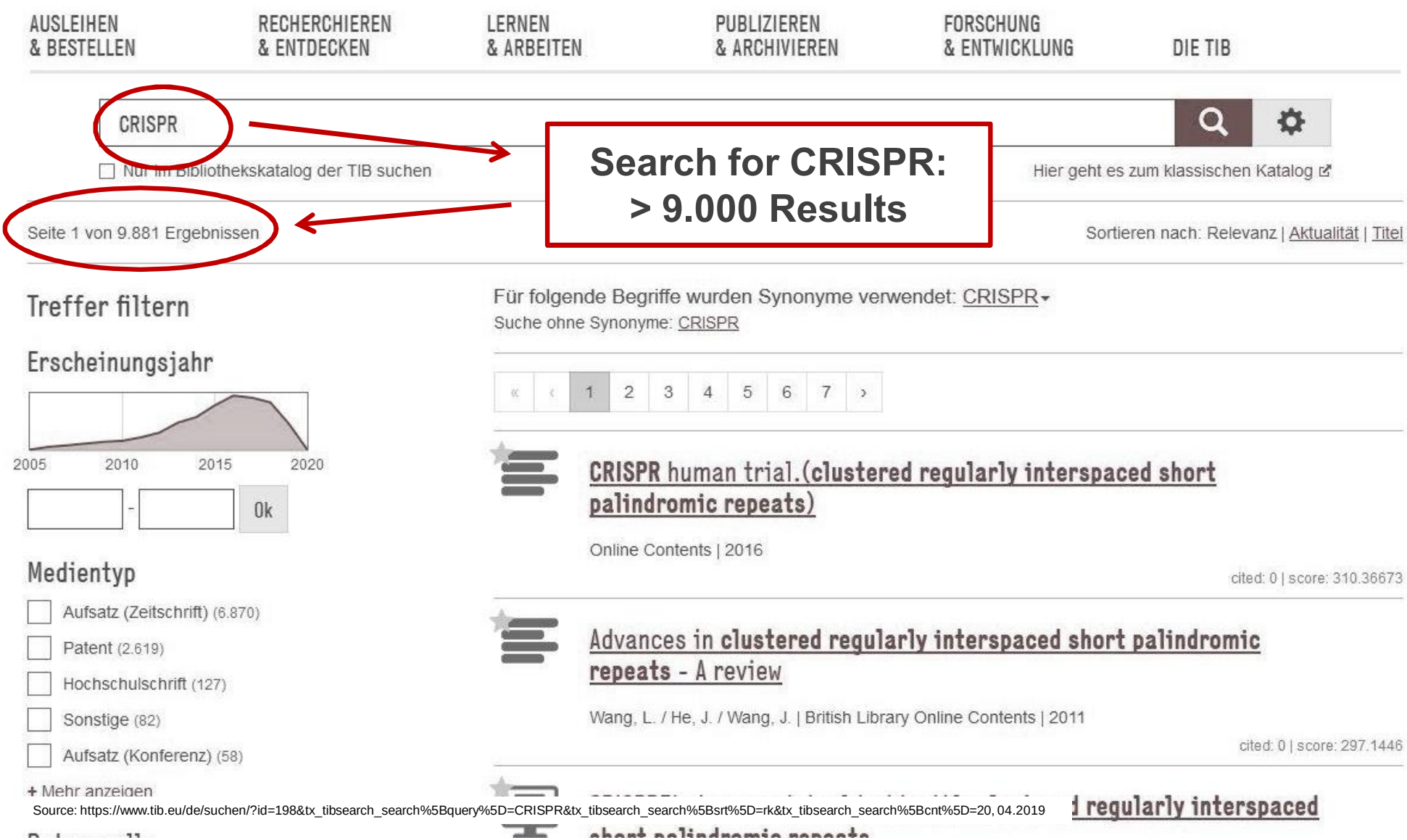
Source: http://xnewlook.com/cad-and-revit-3d-design.html/bill-ferguson-portfolio-computer-graphics-games-cad-related-3d-models-cad-and-revit-design

Root Cause –
Deficiency of Scholarly Communication?

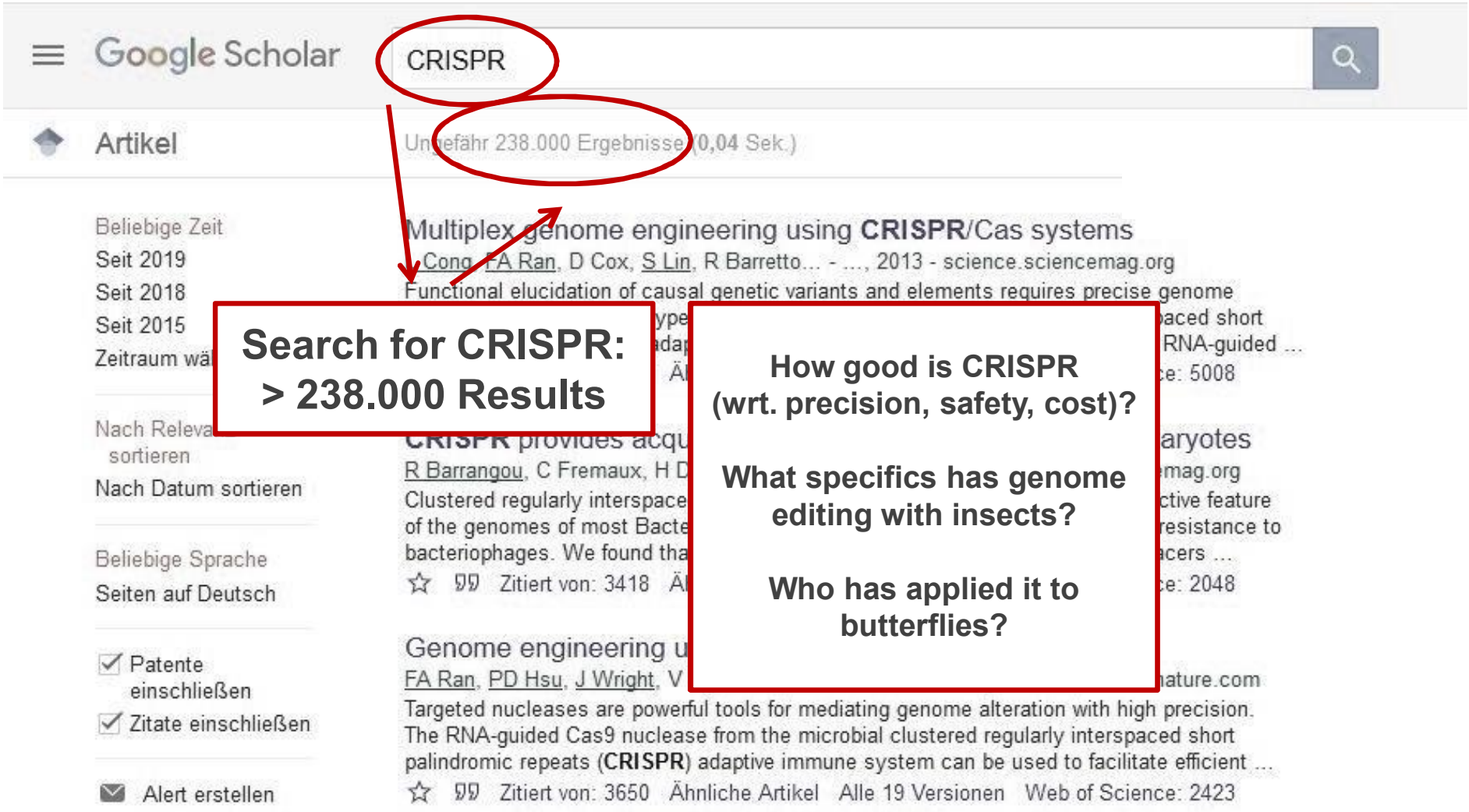
Lack of…

Transparency	Integratability	Machine assistance
information is hidden in text	fitting different research results together	unstructured content is hard to process

Identifyability	Collaboration	Overview
of concepts beyond metadata	one brain barrier	Scientists look for the needle in the haystack



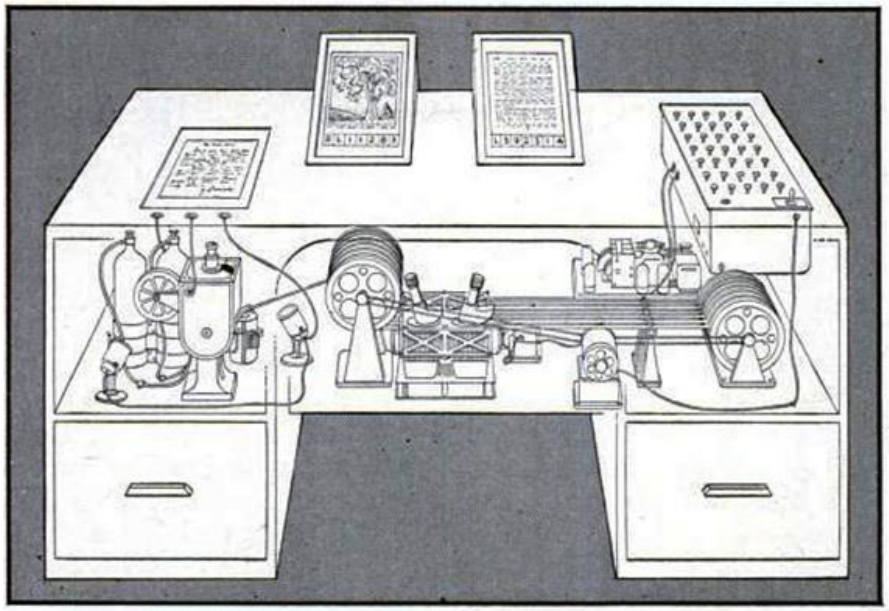
Source: https://www.tib.eu/de/suchen/?id=198&tx_tibsearch_search%5Bquery%5D=CRISPR&tx_tibsearch_search%5Bsrt%5D=rk&tx_tibsearch_search%5Bcnt%5D=20, 04.2019



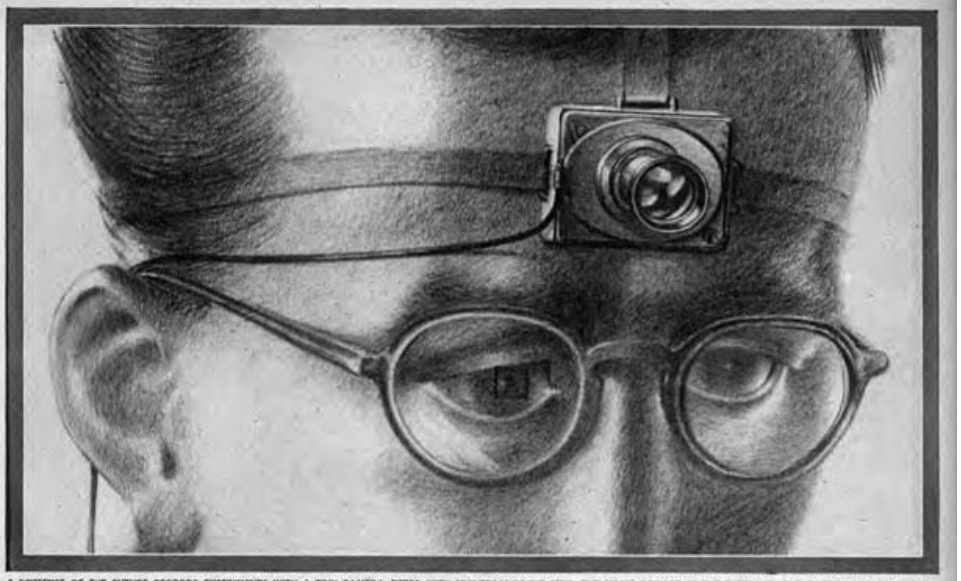
Source: https://scholar.google.de/scholar?hl=de&as_sdt=0%2C5&q=CRISPR&btnG=, 04.2019

How can we fix it?

Realizing Vannevar Bush‘s vision of Memex



Source: http://photos1.blogger.com/blogger/5874/1071/1600/Memex.jpg



A SCIENTIST OF THE FUTURE RECORDS EXPERIMENTS WITH A TINY CAMERA FITTED WITH UNIVERSAL-FOCUS LENS. THE SMALL SQUARE IN THE EYEGLASS AT THE LEFT SIGHTS THE OBJECT

AS WE MAY THINK

A TOP U. S. SCIENTIST FORESEES A POSSIBLE FUTURE WORLD IN WHICH MAN-MADE MACHINES WILL START TO THINK

by VANNEVAR BUSH

DIRECTOR OF THE OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

Condensed from the *Atlantic Monthly*, July 1945

This has not been a scientists' war; it has been a war in which all have had a part. The scientists, burying their old professional competition in the demand of a common cause, have shared greatly and learned much. It has been exhilarating to work in effective partnership. What are the scientists to do next?

For the biologists, and particularly for the medical scientists, there can be little indecision, for their war work has hardly required them to leave the old paths. Many indeed have been able to carry on their war research in their familiar peacetime laboratories. Their objectives remain much the same.

It is the physicists who have been thrown most violently off stride, who have left academic pursuits for the making of strange destructive gadgets, who have had to devise new methods for their unanticipated assignments. They have done their part on the devices that made it possible to turn back

been part of a great team. Now one asks where they will find objectives

ress, and the effort to bridge between disciplines is correspondingly superficial.

Professionally our methods of transmitting and reviewing the results of research are generations old and by now are totally inadequate for their purpose. If the aggregate time spent in writing scholarly works and in reading them could be evaluated, the ratio between these amounts of time might well be startling. Those who conscientiously attempt to keep abreast of current thought, even in restricted fields, by close and continuous reading might well shy away from an examination calculated to show how much of the previous month's efforts could be produced on call.

Mendel's concept of the laws of genetics was lost to the world for a generation because his publication did not reach the few who were capable

ificant attainments become lost in the mass

Publication has been extended far beyond our present ability to make real

Source: http://tntindex.blogspot.com/2014/10/tabletalk-vannevar-bushs-memex.html

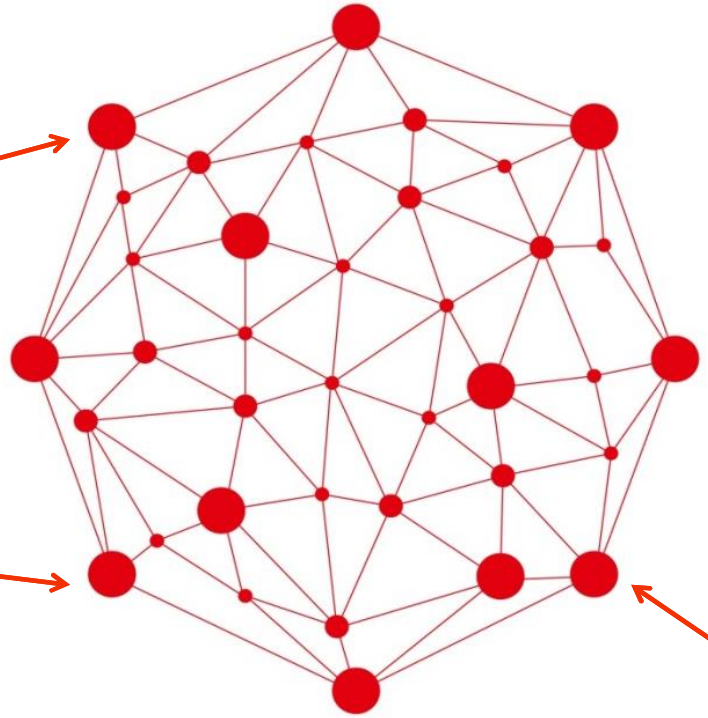
Concepts

Overarching Concepts

- Research problems
- Definitions
- Research approaches
- Methods

Artefacts

- Publications
- Data
- Software
- Image/Audio/Video
- Knowledge Graphs / Ontologies



Domain specific Concepts

Mathematics	Physics	Chemistry	Computer Science	Technology	Architecture
Å Definitions Å Theorems Å Proofs Å Methods Å é	Å Experiments Å Data Å Models Å é	Å Substances Å Structures Å Reactions Å é	Å Concepts Å Implemen-tations Å Evaluations Å é	Å Standards Å Processes Å Elements Å Units, Sensor data	Å Regulations Å Elements Å Models Å é

Linked Data Principles

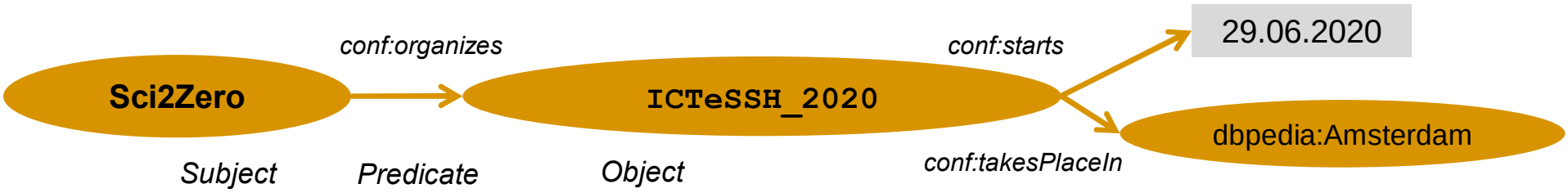
Addressing the neglected third V (Variety)

1. Use **URIs** to **identify** the ñthingsò in your data
2. Use **http:// URIs** so people (and machines) can **look** them **up** on the web
3. When a URI is looked up, **return** a **description** of the thing **in** the W3C **Resource Description Format (RDF)**
4. Include **links to related things**

http://www.w3.org/DesignIssues/LinkedData.html

RDF & Linked Data in a Nutshell

1. Graph based RDF data model consisting of S-P-O statements (facts)



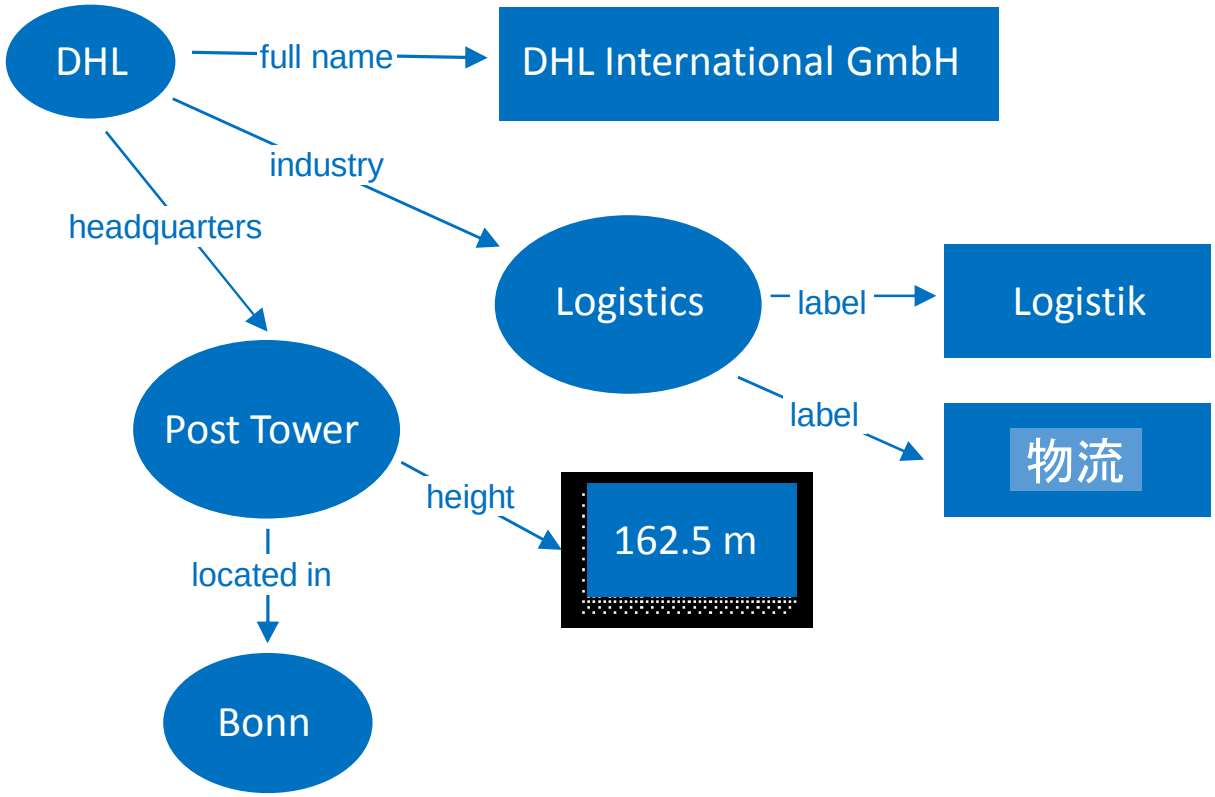
2. Serialised as RDF Triples:

```
Sci2Zero            conf:organizes      ICTeSSH_2020 .
ICTeSSH_2020        conf:starts         "2020-06-29"^^xsd:date .
ICTeSSH_2020        conf:takesPlaceAt   dbpedia:Amsterdam .
```

3. Publication under URL in Web, Intranet, Extranet

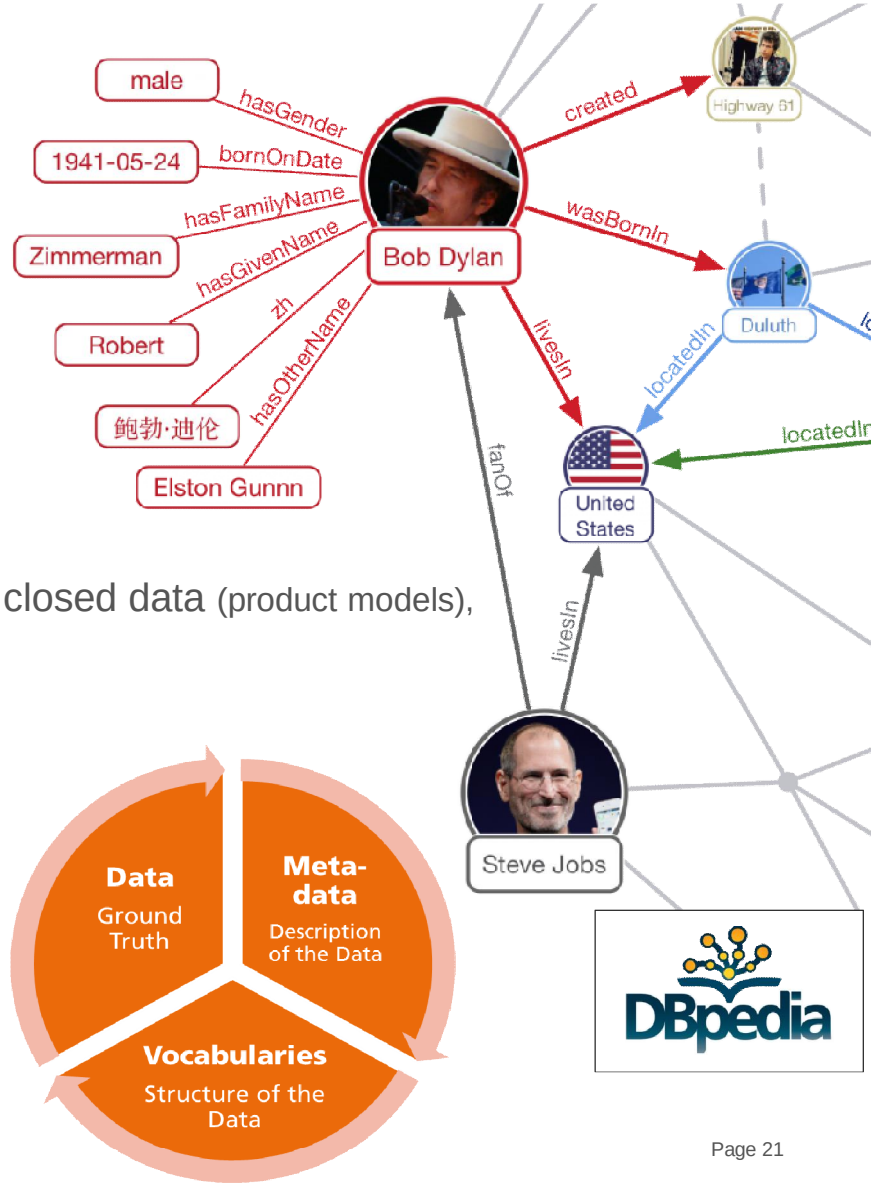
Linked Data

Creating Knowledge Graphs with RDF



Knowledge Graphs – A definition

- Fabric of concept, class, property, relationships, entity desc.
- Uses a knowledge representation formalism (RDF, OWL)
- Holistic knowledge (multi-domain, source, granularity):
  - **instance data** (ground truth),
    - open (e.g. DBpedia, WikiData), private (e.g. supply chain data), closed data (product models),
  - derived, aggregated data,
  - **schema data** (vocabularies, ontologies)
  - **meta-data** (e.g. provenance, versioning, documentation licensing)
  - comprehensive **taxonomies** to categorize entities
  - **links** between internal and external data
  - **mappings** to data stored in other systems and databases



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Industry Knowledge Graph Adoption

https://www.slideshare.net/Frank.van.Harmelen/adoption-of-knowledge-graphs-late-2019

Chemistry Example: CRISPR Genome Editing

Cold Spring Harbor Laboratory

bioRχiv

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A practical guide to CRISPR/Cas9 genome editing in Lepidoptera

Posted June 22, 2017.

Linlin Zhang, Robert Reed

doi: https://doi.org/10.1101/130344

Now published in *Diversity and Evolution of Butterfly Wing Patterns* doi: 10.1007/978-981-10-4956-9_8

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Subject Area

Genetics

Abstract

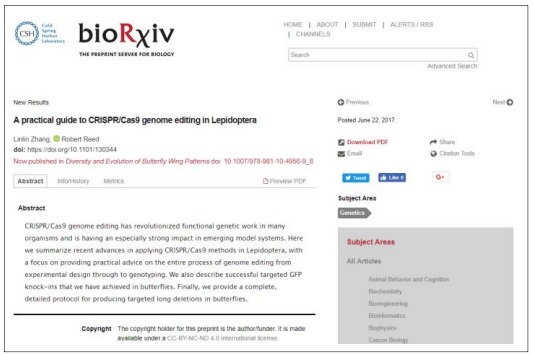
CRISPR/Cas9 genome editing has revolutionized functional genetic work in many organisms and is having an especially strong impact in emerging model systems. Here we summarize recent advances in applying CRISPR/Cas9 methods in Lepidoptera, with a focus on providing practical advice on the entire process of genome editing from experimental design through to genotyping. We also describe successful targeted GFP

Subject Areas

All Articles

Source: https://cacm.acm.org/system/assets/0002/2618/021116_Google_KnowledgeGraph.large.jpg?1476779500&1455222197

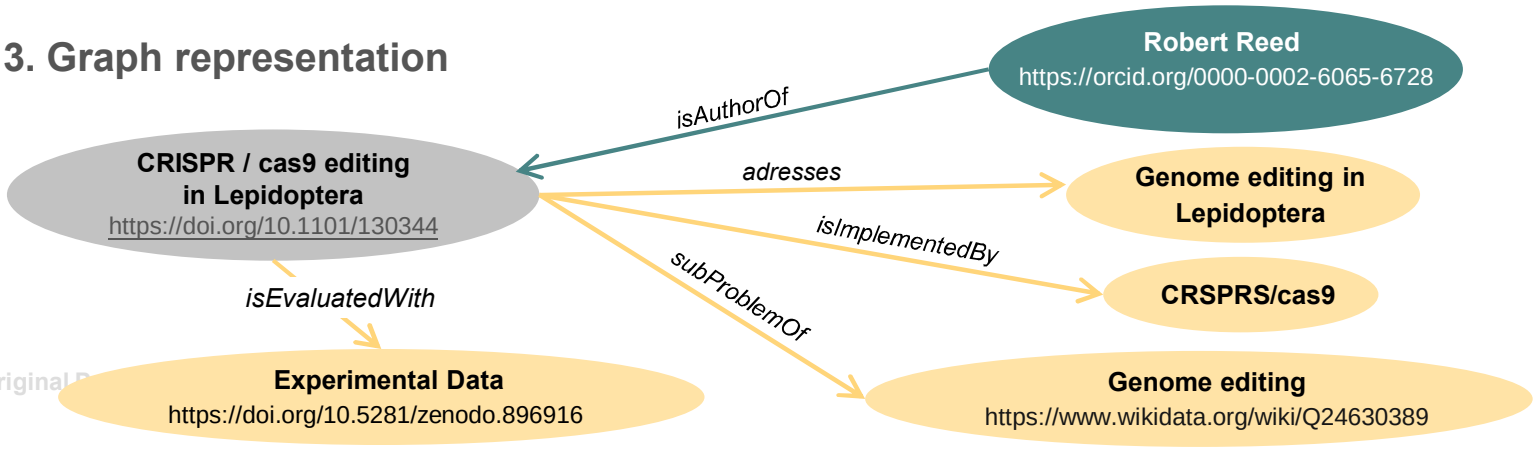
Chemistry Example: Populating the Graph



2. Adaptive Graph Curation & Completion

Author	Robert Reed
Research Problem	Genome editing in Lepidoptera
Methods	CRISPR / cas9
Applied on	Lepidoptera
Experimental Data	https://doi.org/10.5281/zenodo.896916

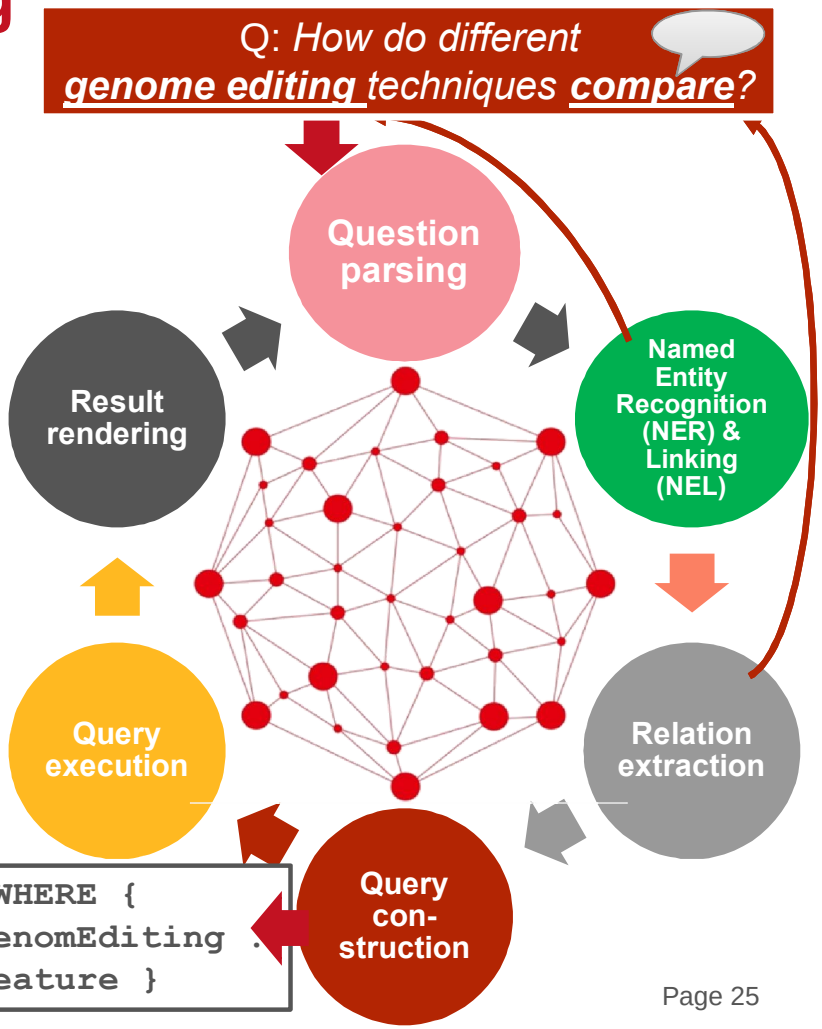
3. Graph representation



Exploration and Question Answering

Research Challenge:

- Intuitive exploration leveraging the rich semantic representations
- Answer natural language questions




```
SELECT Approach, Feature WHERE {
  Approach  adresses     GenomEditing .
  Approach  hasFeature   Feature }
```


[1] K. Singh, S. Auer et al: *Why Reinvent the Wheel? Let's Build Question Answering Systems Together.* The Web Conference (WWW 2018).

Result:
Automatic Generation of Comparisons / Surveys

Q: How do different **genome editing** techniques **compare**?

Engineered Nucleases	Site-specificity	Safety	Ease-of-use / costs/ speed
zinc finger nucleases (ZFN)	++ 9-18nt	+	-- $$$: screening, testing to define efficiency
transcription activator-like effector nucleases (TALENs)	+++ 9-16nt	++	++ Easy to engineer 1 week / few hundred dollar
engineered meganucleases	+++ 12-40 nt	0	-- $$$ Protein engineering, high-throughput screening
CRISPR system/cas9	++ 5-12 nt	-	+++ Easy to engineer few days / less 200 dollar

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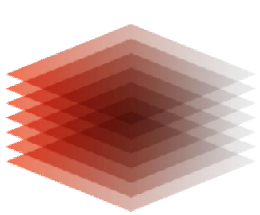

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Demo: Open Research Knowledge Graph

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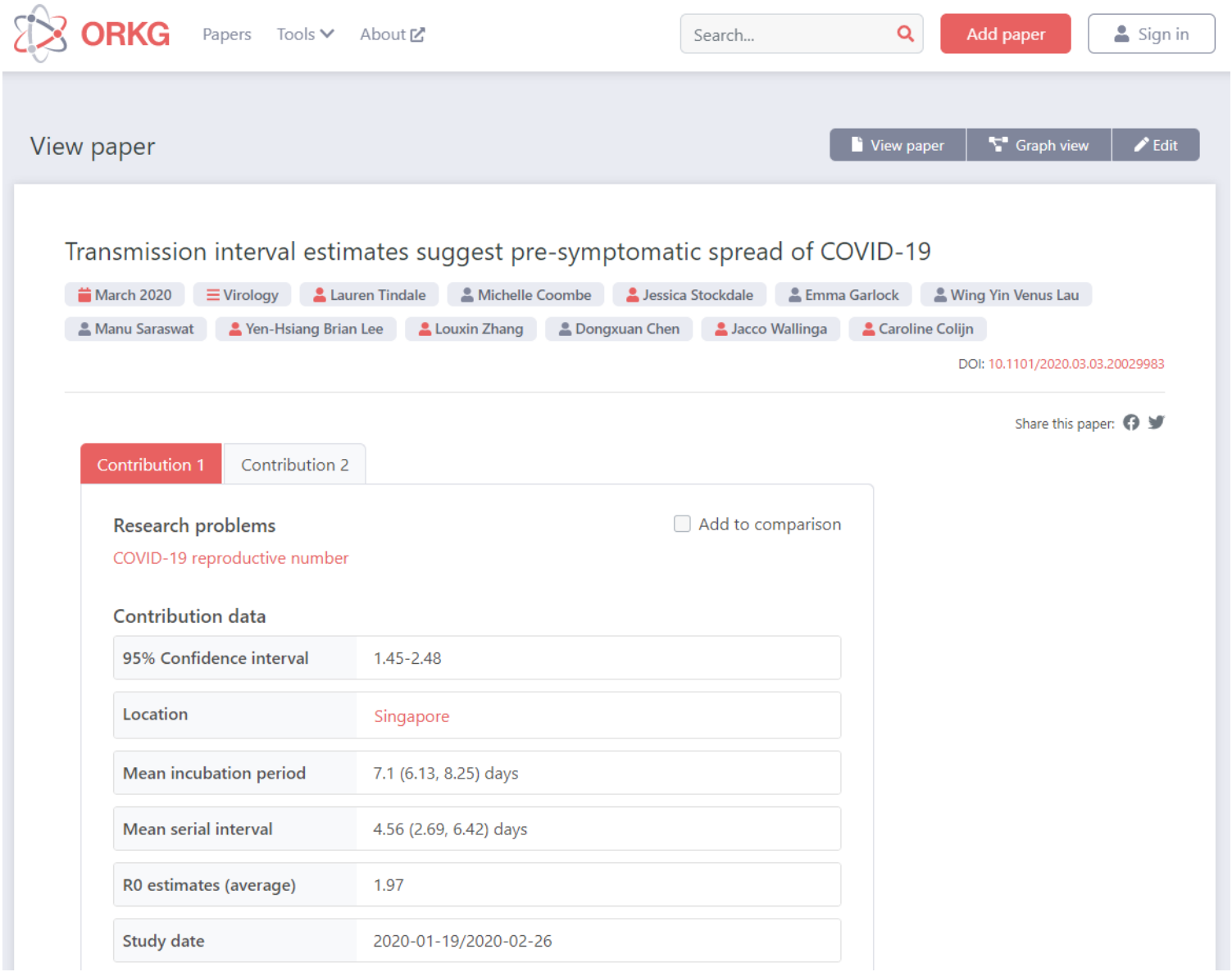
Properties	Estimation of the epidemic properties of the 2019 novel coronavirus: A mathematical modeling study Contribution 1 - 2020	Estimation of the epidemic properties of the 2019 novel coronavirus: A mathematical modeling study Contribution 2 - 2020	Estimation of the epidemic properties of the 2019 novel coronavirus: A mathematical modeling study Contribution 3 - 2020	Transmission potential of COVID-19 in Iran Contribution 1 - 2020	Transmission potential of COVID-19 in Iran Contribution 2 - 2020	Estimating the generation interval for COVID-19 based on symptom onset data Contribution 1 - 2020
Has research problem	COVID-19 reproductive number	COVID-19 reproductive number	COVID-19 reproductive number	COVID-19 reproductive number	COVID-19 reproductive number	COVID-19 reproductive number
Location	Wuhan City, China	Wuhan City, China	Wuhan City, China	Iran	Iran	Singapore
Study date	2020-01-10/2020-01-23	2020-01-23/2020-02-08	2020-01-10/2020-02-08	2020-02-19/2020-02-29	2020-02-19/2020-02-29	2020-01-21/2020-02-26
R0 estimates (average)	4.38	3.41	3.39	3.6	3.58	1.27
95% confidence interval	3.63-5.13	3.16-3.65	3.09-3.70	3.2-4.2	1.29-8.46	1.19-1.36
Method	a weighted average of Exponential growth, Maximum likelihood, Sequential Bayesian, Time-dependent reproduction numbers, and SEIR model basic reproduction numbers by calculating weights from a Poisson loss function	a weighted average of Exponential growth, Maximum likelihood, Sequential Bayesian, Time-dependent reproduction numbers, and SEIR model basic reproduction numbers by calculating weights from a Poisson loss function	a weighted average of Exponential growth, Maximum likelihood, Sequential Bayesian, Time-dependent reproduction numbers, and SEIR model basic reproduction numbers by calculating weights from a Poisson loss function	generalized growth model	based on the calculation of the epidemic's doubling times: estimated epidemic doubling time of 1.20 (95% CI, 1.05, 1.44) days	generation interval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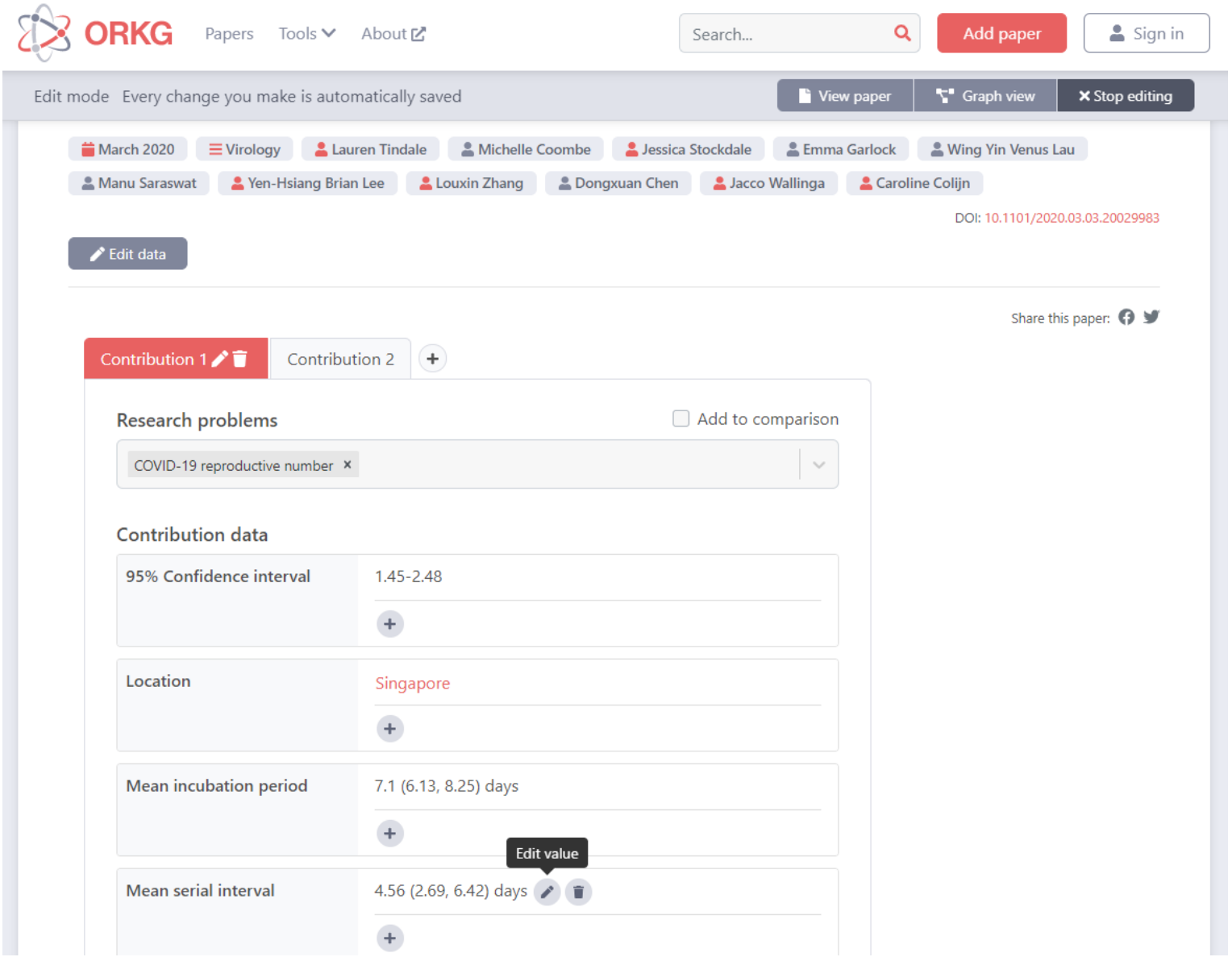
Mean incubation period
7.1 (6.13, 8.25) days
Mean serial interval
4.56 (2.69, 6.42) days
R0 estimates (average)
1.97
Study date
2020-01-19/2020-02-26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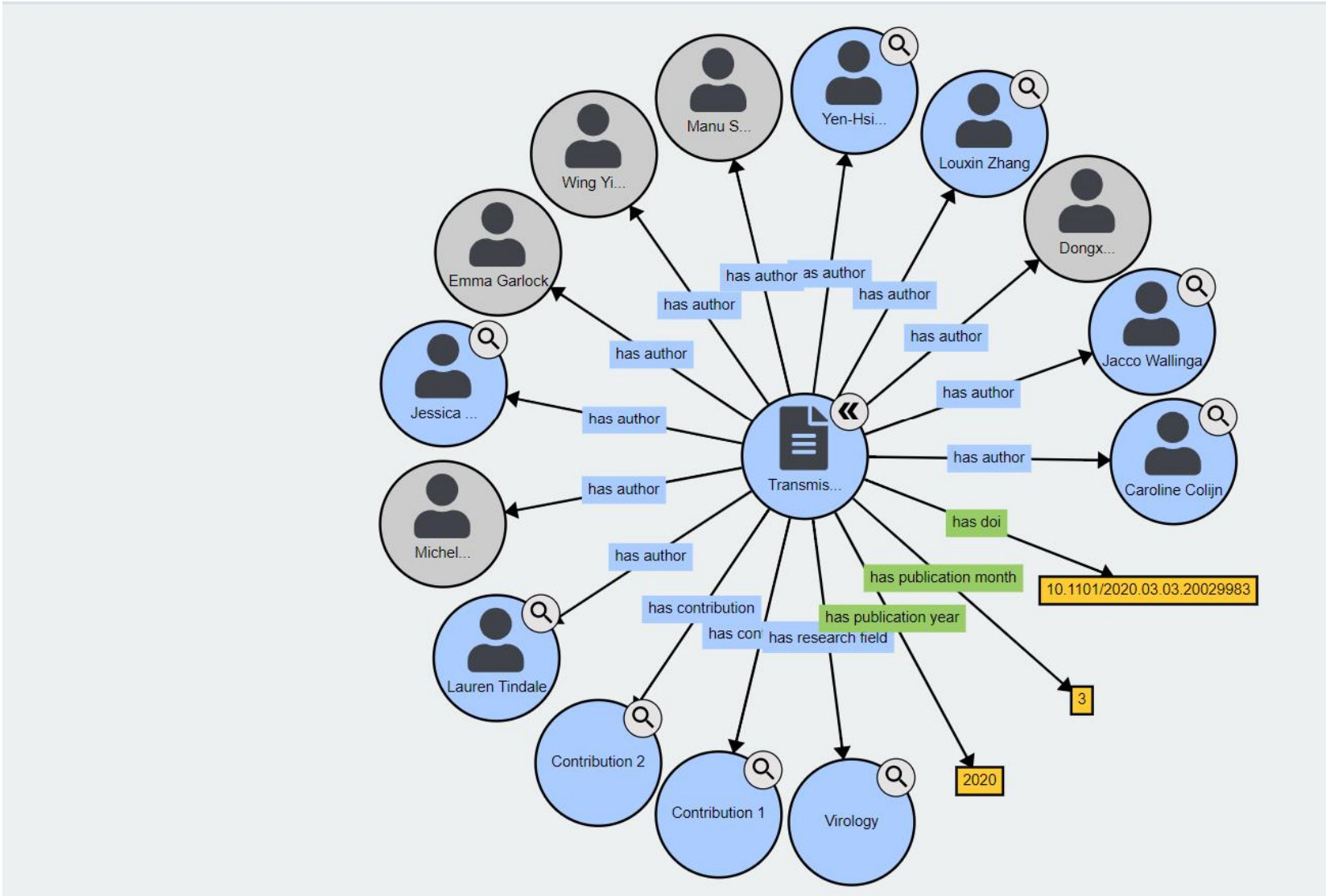

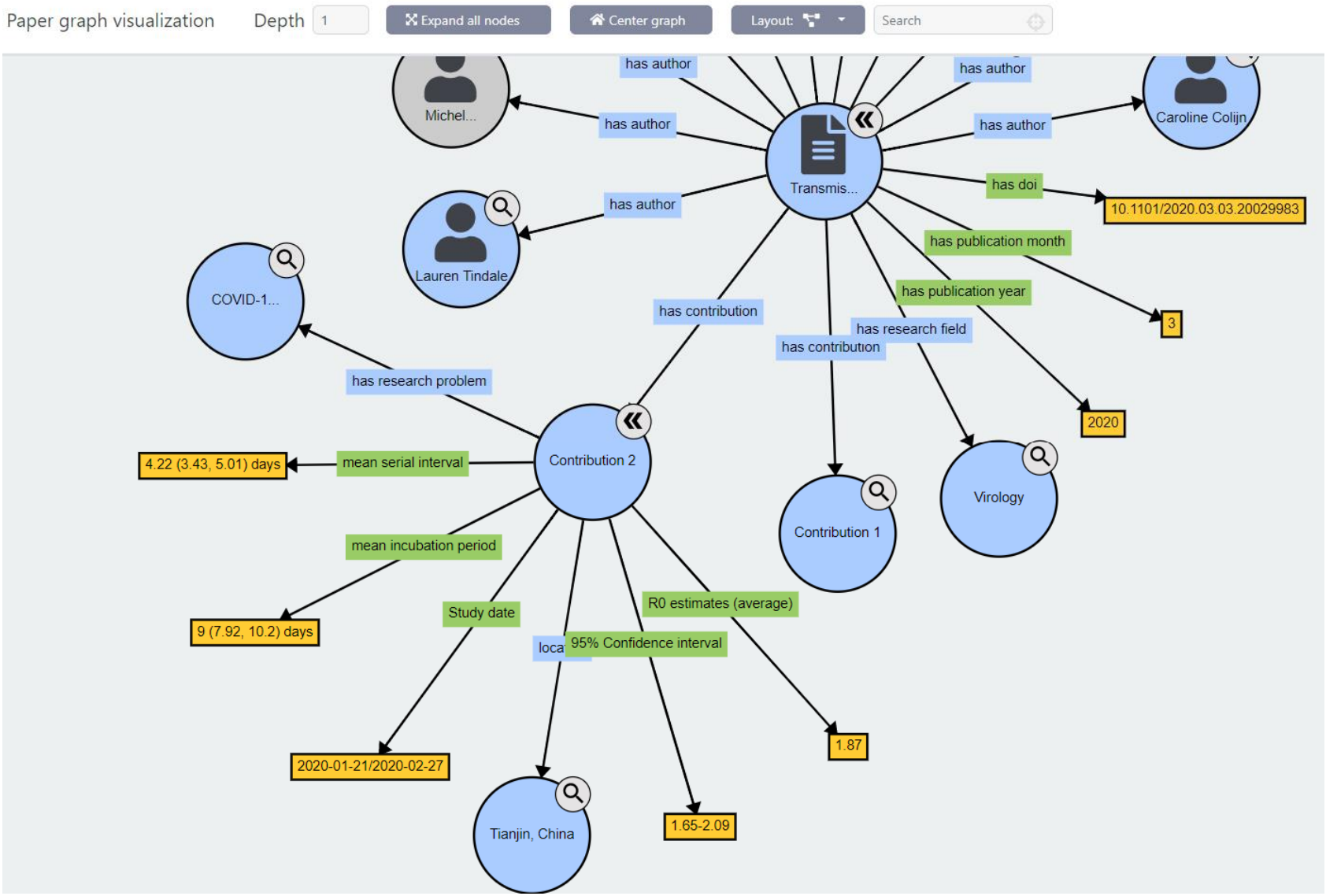
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has contribution
3
has research problem
2020
Contribution 2
4.22 (3.43, 5.01) days
mean serial interval
Virology
Contribution 1
mean incubation period
9 (7.92, 10.2) days
Study date
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95% Confidence interval
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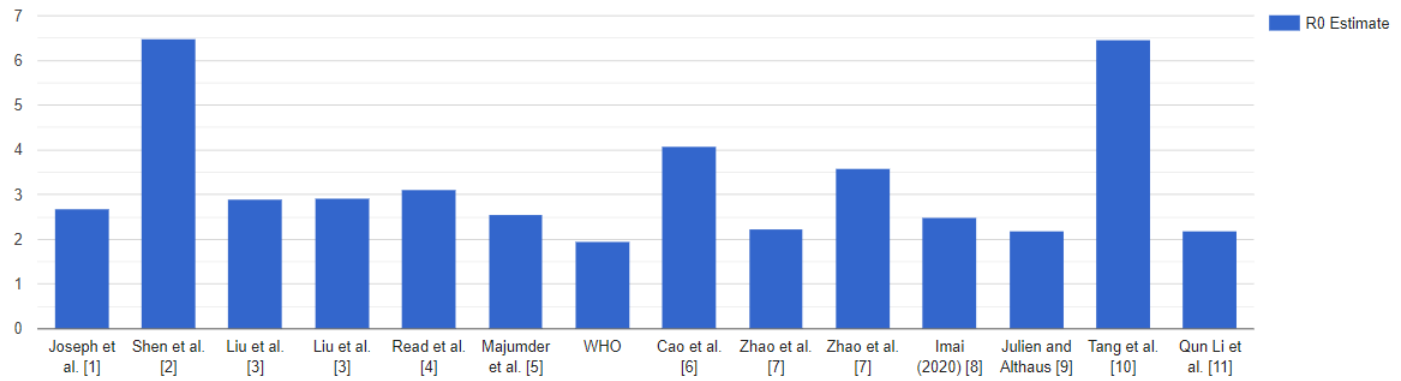
2020-01-21/2020-02-27
Tianjin, China
1.65-2.09

Bar Chart



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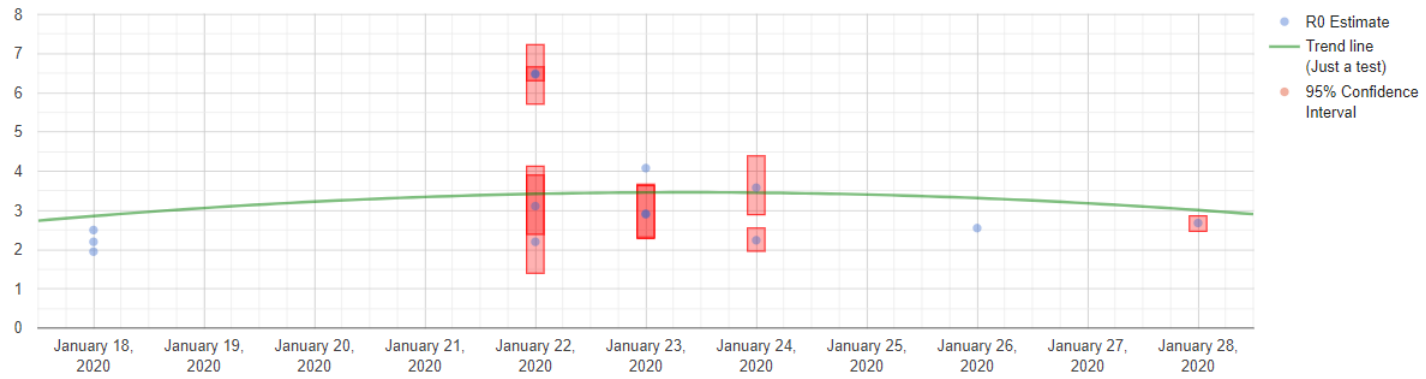

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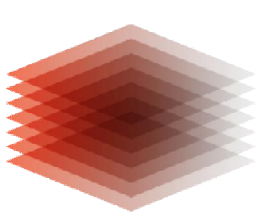

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Social Science Examples

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Dr. Javad Chamanara


Dr. Jennifer D'Souza

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Manuel Prinz


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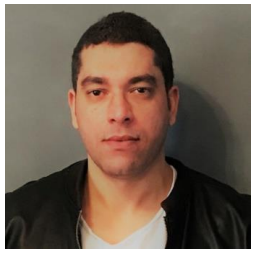
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Dr. Michael Martin


Natanael Arndt

Project Management


Alex Garatzogianni

Conclusions

- We need to **reinvent scholarly communication**
- **Knowledge Graphs are perfectly suited to capture research contributions in a structured and semantic way making them human and machine interpretable**
- With our **Open Research Knowledge Graph initiative we aim to establish a registry for research contributions**
- Curation and **synergistic combination of human, expert and machine intelligence** is a challenge

Stay tuned

- https://tib.eu
- Consider creating an ORKG observatory for your domain
- Mailinglist/group: https://groups.google.com/forum/#!forum/orkg
- Open Research Knowledge Graph: https://orkg.org
- ERC Consolidator Grant ScienceGRAPH on the topic

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