A smart literature exploration environment for COVID-19 literature

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Abstract

Historically the vast amount of knowledge that experts publish has been increasing in such a pace that keeping up to date and having a full perspective, even in particular topics, has become quite challenging. Such is the case of the current COVID-19 pandemic were there are so many clinical notes, experiments, expert observations around the world that doctors, researchers, and public authorities struggle to explore pieces of related but not explicitly connected knowledge concerning to their respective duties.

To simplify the process of exploration of the literature related to COVID-19, we propose a smart literature analysis environment, which includes several NLP-powered components to enable a more efficient reading process. In particular, we propose a semantically-guided transversal reading. We believe that this type of reading can significantly benefit the process of grasping the prominent opinion and state-of-the-art of a particular aspect. Our strategy to provide this feature was to interlink all semantically related sentences by semantic-textual-similarity (STS).

Besides, we enrich the literature with named-entity recognition and disambiguation (NERD), using the major life science databases as entity sources, enable named-entity searches, provide network-graphs of the most interconnected publications and, an interactive tool to highlight the most central statements within an article. All these capabilities are embedded in an easy to use web environment[1].

1 Introduction

The current pandemic took the world by surprise in all aspects. Among several difficulties, it also brought to the fore a problem that has become increasingly urgent over the years: That the knowledge we are producing is stored and shared in a manner that is not in-line with the pace and accessibility that is needed.

We have witnessed an enormous effort and solidarity that all kinds of involved actors around the world had put in reporting and sharing their experiences and findings. However, these efforts have been often undermined by the lack of easy ways to find a particular piece of knowledge or, if found, to weigh the degree of support and consensus it has.

One way to help tackle the emergency is to provide users with assisted means to explore the literature.

The goal of the system described in this paper is to facilitate the identification of central items of knowledge within a collection of publications. We addressed it by taking some insights of the reading comprehension analysis from the psycholinguistic point of view which led us to propose a combination of Natural Language Processing (NLP) tools that respond to 4 main objectives: provide a shallow but fast view of how publications are related through a network of semantic connections, facilitate skim reading by highlighting the more central sentences in an article, make more sense of a publication set by enabling browsing across semantically related statements and, enrich the reader context by Named-Entity Recognition and Disambiguation.

We developed these NLP strategies and integrated them in a web environment to make them easily available to any user. The application is already online and we are currently processing the firsts collections.

2 Background

To grasp the nitty-gritty of a document or a collection of them is clearly much more than summariz-

[1] http://covid19.ccg.unam.mx:82/

ing or finding interconnections but, comprehend what is expressed in the texts is part of the process. There is a long and solid research about the reading-comprehension phenomena which includes a myriad of sub-tasks. Among these sub-tasks it is to identify the topic, to make sense of the way information is organized and, to extract the main idea (Baumann, 1984).

We think that there are some interesting similarities between trying to get the main-idea of a single text and of a collection of them. Two key factors are the identification of words relevant in the context and the recognition of the relationships between the text propositions (Graesser et al., 1994; Grabe, 2004). The first one give important clues to what the main information is (Wilawan, 2012; Hoey, 1991). The second help to understand the way in which information is organized (Grabe, 2004; Crosson and Lesaux, 2013).

Automatic signaling these factors can play a potential support for the reader to enhance his comprehension (Degand and Sanders, 2002). Even though going beyond the mere identification is appealing, we think that doing that could misguide, in a restrictive way, the reader comprehension. This has been argued by some constructionist theories that postulate that during reading the meaning representations are generated online and that the readers generate representation that address their personal goals (Graesser et al., 1994). Therefore highlight relevant terms and signalize the relationships is a good trade-off between automatic-support and freedom.

3 Methodology

In this section, we first briefly describe the general pipeline and system architecture, and then the NLP methods and how they are leveraged.

3.1 System architecture and pipeline

First the publication collection is processed by our PDF-content-extractor which produces a set of files with text and stylographic data. These files are provided as input to the Semantic Textual Similarity (STS) and Named-Entity Recognition and Disambiguation (NERD) tasks which are performed individually and off-line. The publications' text and the annotated entities, resulting from the NERD step, are indexed in an ElasticSearch instance. The STS scores and its involved sentences indexes are stored in a key-value database (SSDB[2]). Finally, the collection name and metadata is registered in a MongoDB instance.

The front-end is composed by an Angular application and a Java API which access the above mentioned databases; all deployed as docker containers.

3.2 Semantic Textual Similarity

To evaluate all semantic similarities within a set of documents the STS has to be computed for all combinations of each sentence versus all the others, i.e., $\binom{N}{2} - N$ where N is the number of all the sentences in the set; which means an upper bound complexity of $O(N^2)$. So we opted for computing embeddings individually for all sentences and, after, measure the cosine between each pair of embeddings.

We used SciBERT (Beltagy et al., 2019), an unsupervised transformer language model pre-trained in the scientific literature. It was selected over BioBERT (Beltagy et al., 2019) because COVID-19 corpora include literature from other areas besides biological sciences, e.g., social sciences, public health, psychology, etc. Using SciBERT we mapped tokens to embeddings and then applied mean pooling to get one fixed-sized sentence vector. Due to the lack of STS corpora specific to the COVID-19 literature, we did not apply any fine-tuning.

Although we did not have an STS corpus for COVID-19 literature, we performed an indirect validation over one corpus of the topic of transcriptional-regulation (Lithgow-Serrano et al., 2019) (i.e., within the genetics field). We compared SciBERT versus DistilBERT (Sanh et al., 2019) and two versions of InferSent (Conneau et al., 2017) embeddings generated from different pre-trained GLOVE word-embeddings (Pennington et al., 2014), the results are shown in table 1.

Pearson	Spearman	Model
0.686	0.743	SciBERT
0.645	0.620	DistilBERT
0.534	0.584	InferSent GloVe-840B
0.469	0.574	InferSent GloVe SMTR

Table 1: Model correlations

[2] http://ssdb.io/

3.2.1 Interlinking

The interlinks of each sentence (anchor) are the N more semantically similar sentences within the publication set. Those target sentences can be in the same publication as the anchor (internal) or in others publications (external). We also filter-out those interlinks with a STS below a threshold $\theta = 0.85$.

It is worth noticing that if s_j is within the best connections of s_i ($s_i \to s_j$) does not necessarily hold the other way around ($s_j \to s_i$).

3.2.2 Network of publications

The network of publications is a directed graph with nodes representing publications and edges the semantic connections among them. There are two links between two publications (A, B): the edge that summarize (eq. 1) all sentences from A that target sentences in B and, the edge that represent sentences from B targeting sentences in A.

$$edge(A \to B) = \sum^{|s_i \in A \wedge s_j \in B \wedge s_i \to s_j|} STS(s_i, s_j) \tag{1}$$

3.2.3 Highlight of more central sentences

The identification of the more central sentences in a publication is also based in the STS scores. For this task we only use the internal interlinks i.e., links connecting sentences in the same document. The centrality of a sentence i within a document A is given by the weighted sum of the connections of s_i to other sentences plus the connections from other sentences to s_i (eq. 2). The current weights were empirically set at $\psi = 0.35$ and $\omega = 0.65$, i.e., to evaluate the centrality of a sentence we give more importance to the connections it receives.

$$\Xi(s_i) = \sum^{|sentences_A|} \psi STS(s_i \to s_j) + \omega STS(s_j \to s_i) \tag{2}$$

3.3 Named-entity recognition and disambiguation

The NERD capabilities are provided by the OntoGene's Biomedical Entity Recogniser (OGER) (Furrer et al., 2019), a state-of-the-art biomedical annotator which in turn depends on the Bio Term Hub (BTH) (Ellendorff et al., 2015). BTH is a combined terminological resource created by dynamically sourcing entity names and their identifiers from reference databases.

OGER was integrated using its RESTful web service that allows remotely batch annotate a collection of documents. We opted for the TSV output which was later converted to the ElasticSearch annotation format.

4 Results

Figure 1 shows the reading environment. From right to left: first the toolbar allows easy access to the features that can be used when reading a publication; next the tool-details panel contains information and controls specific to the active tool; following, the PDF reader display the source PDF when available; at the middle there is the eagle-view panel that shows a global perspective of the document and where the highlighted sentences are located; finally, the processed content panel display the publication sentences (one per line), the annotated entities (if the annotation tool is active) and the hyperlinks to access interlinked sentences.

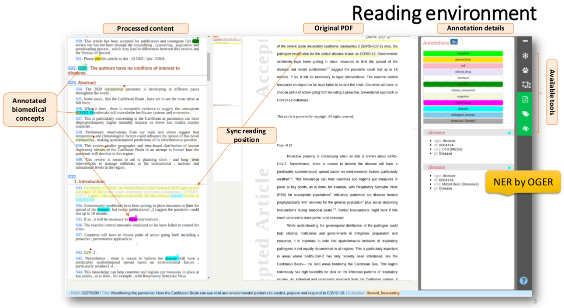
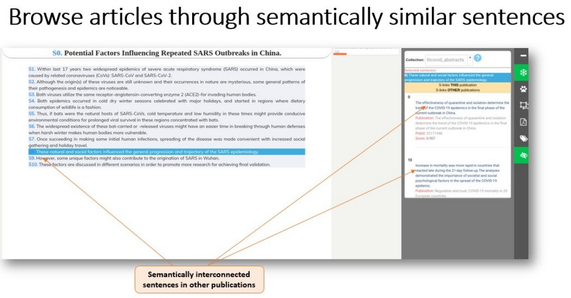


Figure 1: Reading component with highlighted named-entities.

The index of each sentence in the content-panel is a hyperlink that trigger the *interlink-tool* (fig. 2). If activated, the tool-detail panel display a list of internal and external sentences semantically related to the selected one. The list of internal relations works as a fast overview of the progression of the idea through the document and, the list of external relations is a summary of potential supporting statements over the publications collection. If the user want to inspect any of the target sentences in their respective contexts, he/she can click on the interlink and the content-panel would be updated to show the new content and focus the target sentence. In this way, the user can continue his reading across different publications (of the same collection) chasing the statements that he is interested in.

When the *highlighter-tool* is active (fig. 4) the



Browse articles through semantically similar sentences

S0. Potential Factors Influencing Repeated SARS Outbreaks in China.

S1. Within last 17 years two widespread epidemics of severe acute respiratory syndrome (SARS) occurred in China, which were caused by related coronaviruses (CoVs): SARS-CoV and SARS-CoV-2.
S2. Although the origin(s) of these viruses are still unknown and their occurrences in nature are mysterious, some general patterns of their pathogenesis and epidemics are noticeable.
S3. Both viruses utilize the same receptor-angiotensin-converting enzyme 2 (ACE2)-for invading human bodies.
S4. Both epidemics occurred in cold dry winter seasons celebrated with major holidays, and started in regions where dietary consumption of wildlife is a fashion.
S5. Thus, if bats were the natural hosts of SARS-CoVs, cold temperature and low humidity in these times might provide conducive environmental conditions for prolonged viral survival in these regions concentrated with bats.
S6. The widespread existence of these bat-carried or -released viruses might have an easier time in breaking through human defenses when harsh winter makes human bodies more vulnerable.
S7. Once succeeding in making some initial human infections, spreading of the disease was made convenient with increased social gathering and holiday travel.
These natural and social factors influenced the general progression and trajectory of the SARS epidemiology.
S9. However, some unique factors might also contribute to the origination of SARS in Wuhan.
S10. These factors are discussed in different scenarios in order to promote more research for achieving final validation.

Collection: litcovid_abstracts

Selected sentence:
8) These natural and social factors influenced the general progression and trajectory of the SARS epidemiology.

S-links THIS publication
S-links OTHER publications

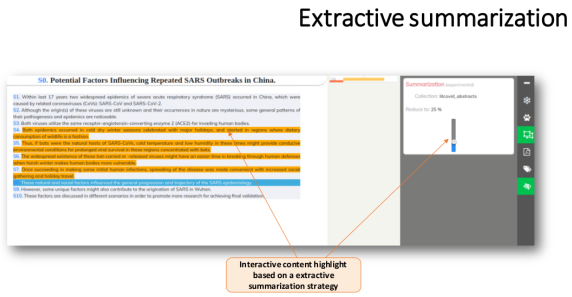
0
The effectiveness of quarantine and isolation determine the trend of the COVID-19 epidemics in the final phase of the current outbreak in China.
Publication: The effectiveness of quarantine and isolation determine the trend of the COVID-19 epidemics in the final phase of the current outbreak in China.
PubId: 32171948
Score: 0.907

10
Increase in mortality was more rapid in countries that reacted late during the 21-day follow-up.The analyses demonstrated the importance of societal and social psychological factors in the spread of the COVID-19 epidemic.
Publication: Regulation and trust: COVID-19 mortality in 25 European countries

Semantically interconnected sentences in other publications

Figure 2: Interlink feature.

tool-detail panel shows a slider that controls the percentage of highlighted sentences. If, for example, the slider is set at 25%, the publication sentences would be ranked by their centrality and only the top 25% would be highlighted.



Extractive summarization

S0. Potential Factors Influencing Repeated SARS Outbreaks in China.

S1. Within last 17 years two widespread epidemics of severe acute respiratory syndrome (SARS) occurred in China, which were caused by related coronaviruses (CoVs): SARS-CoV and SARS-CoV-2.
S2. Although the origin(s) of these viruses are still unknown and their occurrences in nature are mysterious, some general patterns of their pathogenesis and epidemics are noticeable.
S3. Both viruses utilize the same receptor-angiotensin-converting enzyme 2 (ACE2)-for invading human bodies.
S4. Both epidemics occurred in cold dry winter seasons celebrated with major holidays, and started in regions where dietary consumption of wildlife is a fashion.
S5. Thus, if bats were the natural hosts of SARS-CoVs, cold temperature and low humidity in these times might provide conducive environmental conditions for prolonged viral survival in these regions concentrated with bats.
S6. The widespread existence of these bat-carried or -released viruses might have an easier time in breaking through human defenses when harsh winter makes human bodies more vulnerable.
S7. Once succeeding in making some initial human infections, spreading of the disease was made convenient with increased social gathering and holiday travel.
These natural and social factors influenced the general progression and trajectory of the SARS epidemiology.
S9. However, some unique factors might also contribute to the origination of SARS in Wuhan.
S10. These factors are discussed in different scenarios in order to promote more research for achieving final validation.

Summarization (experimental)
Collection: litcovid_abstracts
Reduce to: 25 %

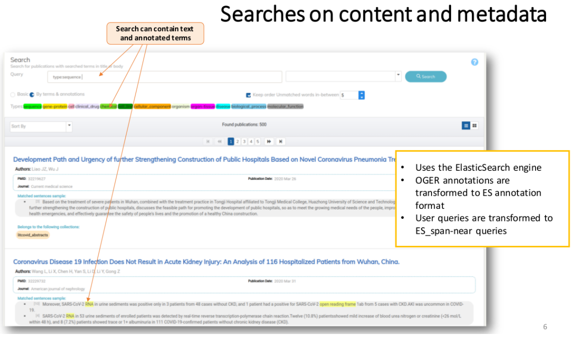
Interactive content highlight based on a extractive summarization strategy

Figure 3: Highlighter based on sentences' centrality.

The system has been designed to handle multiple collections of publications. It is worth noticing that a document can belong to more than one collection and even though the its content remains the same, the generated interlinks depend on the other documents in the collection.

This application has also the capability to generate a network showing how the publications are interlinked within a collection (fig. 1). In this graph the width and the color of the edges are proportional to the interlinks strength so, it can be used as a first approach to graphically inspect which publications are more connected with others or which ones are isolated (e.g., could be due to divergent or contradictory statements). The graph is interactive and when the nodes are selected the immediate edges and connections are emphasized and the publication meta-data is shown in a box above the network.

A search module that leverages the ElasticSearch-features was included. To facilitate user interaction, we developed a very basic meta-language that enables them to search text and annotated entities in the same query. For example, the query "type:clinical_drug | recovery" would search in publications' titles and content for sentences that mention a drug (supposing that OGER identified it) and the word *recovery*.



Searches on content and metadata

Search can contain text and annotated terms

Search
Search for publications with searched terms in title or body
Query: type:sequence|
Search
○ Basic ● By terms & annotations
☑ Keep order Unmatched words in-between 5
Types: sequence gene-protein cell clinical_drug chemical cell_line cellular_component organism organ-tissue disease biological_process molecular_function
Sort By
Found publications: 500
1 2 3 4 5

Development Path and Urgency of further Strengthening Construction of Public Hospitals Based on Novel Coronavirus Pneumonia Tr
Authors: Liao JZ, Wu J
PMID: 32219627
Publication Date: 2020 Mar 26
Journal: Current medical science
Matched sentences sample:
- [1] Based on the treatment of severe patients in Wuhan, combined with the treatment practice in Tongji Hospital affiliated to Tongji Medical College, Huazhong University of Science and Technolog further strengthening the construction of public hospitals, discusses the feasible path for promoting the development of public hospitals, so as to meet the growing medical needs of the people, impro health emergencies, and effectively guarantee the safety of people's lives and the promotion of a healthy China construction.

Belongs to the following collections:
litcovid_abstracts

Coronavirus Disease 19 Infection Does Not Result in Acute Kidney Injury: An Analysis of 116 Hospitalized Patients from Wuhan, China.
Authors: Wang L, Li X, Chen H, Yan S, Li D, Li Y, Gong Z
PMID: 32229732
Publication Date: 2020 Mar 31
Journal: American journal of nephrology
Matched sentences sample:
- [10] Moreover, SARS-CoV-2 RNA in urine sediments was positive only in 3 patients from 48 cases without CKD, and 1 patient had a positive for SARS-CoV-2 open reading frame 1ab from 5 cases with CKD.AKI was uncommon in COVID-19.
- [4] SARS-CoV-2 RNA in 53 urine sediments of enrolled patients was detected by real-time reverse transcription-polymerase chain reaction. Twelve (10.8%) patientsshowed mild increase of blood urea nitrogen or creatinine (<26 mol/L within 48 h), and 8 (7.2%) patients showed trace or 1+ albuminuria in 111 COVID-19-confirmed patients without chronic kidney disease (CKD).

- Uses the ElasticSearch engine
- OGER annotations are transformed to ES annotation format
- User queries are transformed to ES_span-near queries

6

Figure 4: Interlinked-network of a publications.

One important aspect of the application is its usability. This could be affected by the computation time of the NLP tasks, so we took the decision to compute them off-line. Each collection of articles is processed once by each NLP tool and the results are distributed in the system's databases. Thus, when users interact with the web interface this only access previously stored content through an API.

5 Conclusions and future work

Drawing on some solid insights from existing research on reading-comprehension, we have developed a system that uses NLP methodologies implemented with state-of-the-art approaches to explore the COVID-19 literature in novelty ways.

We relied on two NLP methods: Semantic Textual Similarity (STS) and Named-Entity Recognition and Disambiguation (NERD).

STS was implemented using SciBERT, applying mean pooling to get one fixed-sized sentence vectors and then using the cosine measure. We did not apply any fine-tuning.

The NERD depends on OGER, a state-of-the-art biomedical entity recogniser that interoperates with the terminological aggregator Bio-Term Hub.

The outputs of these methods were leveraged in the following implemented tools: networks of semantically connected publications, highlighting of central sentences, NER tagging on publications' content, full-text and named-entities search and, transversal reading by following STS-based links.

Future work would focus on integrating techniques of discourse structure analysis.

References

James F. Baumann. 1984. The Effectiveness of a Direct Instruction Paradigm for Teaching Main Idea Comprehension. *Reading Research Quarterly*, 20(1):93.

Iz Beltagy, Kyle Lo, and Arman Cohan. 2019. SciBERT: Pretrained Contextualized Embeddings for Scientific Text. *arXiv Computer Science*, pages 3615–3620.

Alexis Conneau, Douwe Kiela, Holger Schwenk, Loic Barrault, and Antoine Bordes. 2017. Supervised Learning of Universal Sentence Representations from Natural Language Inference Data.

Amy Crosson and Nonie Lesaux. 2013. Does knowledge of connectives play a unique role in the reading comprehension of English learners and Englishonly students? *Journal of Research in Reading*, 36.

Liesbeth Degand and Ted Sanders. 2002. The impact of relational markers on expository text comprehension in L1 and L2. *Reading and Writing*, 15(7-8):739–757.

Tilia Renate Ellendorff, Adrian Van Der Lek, Lenz Furrer, and Fabio Rinaldi. 2015. A combined resource of biomedical terminology and its statistics. In *CEUR Workshop Proceedings*, volume 1495, pages 39–49.

Lenz Furrer, Anna Jancso, Nicola Colic, and Fabio Rinaldi. 2019. OGER++: Hybrid multi-type entity recognition. *Journal of Cheminformatics*, 11(1):1–10.

William Grabe. 2004. 3. Research on Teaching Reading. *Annual Review of Applied Linguistics*, 24(March 2004).

Arthur C. Graesser, Murray Singer, and Tom Trabasso. 1994. Constructing inferences during narrative text comprehension. *Psychological Review*, 101(3):371–395.

Michael Hoey. 1991. Patterns of lexis in text. *Describing English language.*, Describing:xvii, 276.

Oscar Lithgow-Serrano, Socorro Gama-Castro, Cecilia Ishida-Gutiérrez, Citlalli Mejía-Almonte, Víctor H. Tierrafría, Sara Martínez-Luna, Alberto Santos-Zavaleta, David Velázquez-Ramírez, and Julio Collado-Vides. 2019. Similarity corpus on microbial transcriptional regulation. *Journal of Biomedical Semantics*, 10(1):8.

Jeffrey Pennington, Richard Socher, and Christopher D Manning. 2014. GloVe: Global Vectors for Word Representation. *Proceedings of the 2014 Conference on Empirical Methods in Natural Language Processing*, pages 1532–1543.

Victor Sanh, Lysandre Debut, Julien Chaumond, and Thomas Wolf. 2019. DistilBERT, a distilled version of BERT: smaller, faster, cheaper and lighter.

Sujunya Wilawan. 2012. Fostering Main Idea Comprehension among EFL Learners through Cognitive and Metacognitive Strategies. *International Journal of Humanities and Social Science*, 2(14):46.