LACLICHEV: Exploring the History of Climate Change in Latin America within Newspapers Digital Collections

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Abstract. This paper introduces LACLICHEV (Latin American Climate Change Evolution platform), a data collections exploration environment for exploring historical newspapers searching for articles reporting meteorological events. LACLICHEV is based on data collections’ exploration techniques combined with information retrieval, data analytics, and geographic querying and visualization. This environment provides tools for curating, exploring and analyzing historical newspapers articles, their description and location, and the vocabularies used for referring to meteorological events. The objective being to understand the content of newspapers and identifying possible patterns and models that can build a view of the history of climate change in the Latin American region.

Keywords: Data curation · metadata extraction · data collections exploration · data analytics

1 Introduction

Historical analysis of climate behaviour can provide conclusions about climatologic phenomena and Earth climate behaviour. There exist several scientific efforts to study the history of climate change. The Climate of the Past [1], for example, is an international scientific journal dedicated to the publication and discussion of research articles, short communications, and review papers on Earth’s climate history. The journal covers all temporal scales of climate change

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and variability, from geological time through to multidecade studies of the last century. The Government of Canada provides access to historical observations on climate in Canada starting from 1840 \[2\]. However, these data collections are disconnected and use different reference variables and observation criteria. Even if there is an increasing interest in analysing digital data collections for performing historical studies on climatologic events, the history of climate behaviour is still an open issue that has not revealed missing knowledge.

Technological advances have enabled the understanding of phenomena and complex systems by collecting many different types of information. Data collections are exported under different releases with different sizes, formats (e.g., CSV, text, excel), sometimes with various quality features. Tools helping to understand, consolidate and correlate data collections are crucial. Digital data collections make it possible to have an analytic vision of the evolution of environmental, administrative, economic and social phenomena. In this context, our work deals with data collections that report the emergence of meteorological events (e.g., temperature changes, avalanches, river flow growth, volcano eruptions).

This paper introduces a Latin American Climate Change Evolution platform called LACLICHEV. The objective is to expose and study the history of climate change in Latin America. The hypothesis is that history (in Latin America) is contained in newspapers articles lying in digital collections available in national libraries of four countries, namely Mexico, Colombia, Ecuador and Uruguay. LACLICHEV addresses three issues:

(i) First, newspaper archaeology by chasing articles talking about climatological events using specific vocabulary to discover as many articles as possible. The challenge is choosing the adequate vocabulary to increase chances to get articles actually talking about climatologic events.

(ii) Second, once an article talks about a climatologic event, it is Geo-Temporal tagged with metadata specifying what happened, where and when it happened, its duration and geographical extent. The objective here is to build a climatologic event history.

(iii) Finally, on top of this history, the objective is to run analytics questions and visualize results in maps, given that the content is highly spatial.

The remainder of this paper is organized as follows. Section 2 introduces the curation process that we propose for historical newspapers articles potentially reporting on climatologic events. Section 3 describes the general architecture of LACLICHEV and the experiments we conducted for evaluating it. Section 4 studies approaches that promote datasets exploration for defining the type of analysis possible on top of them. Finally, 5 concludes the paper underlying the contribution and discussing future work.

2 Curating historical newspapers articles

The objective of curating historical newspapers articles is to build a dataset of documents reporting meteorological events and associating them with meta-
data, providing as much information as possible about the reported event. The newspapers curation process is a semi-automatic process devoted to: (i) find articles reporting climatologic events within newspapers articles collections; and (ii) geo-tag and store those articles that report such events for building a database containing the climatologic event history.

Curation tasks are performed on a collection of textual digital documents with minimum associated meta-data, particularly those used by digital libraries that own the collections. Each library adopts its meta-data schema, but in general, they specify the newspaper’s name, the country, the day and number, the number of pages, the window time in which it circulated. Libraries export the meta-data schema used to describe these resources and align them to standards used by digital libraries. The curation process generates data structures that provide an abstract representation of the content of each article describing an event. We propose a meteorological event knowledge model (see Figure 1) to represent climate event reports in digital documents. The objective is to describe events from different perspectives using the information from the articles and newspapers that report them and complete their description with domain knowledge also described in the model. As shown in Figure 1 events are associated with the newspaper article(s) that describe them (reading from right to left). Each article can have meta-data that curates it, which points to its "raw" content that has been processed and annotated with linguistic labels. Annotation and curation tasks can be recurrent and include a human-in-the-loop strategy for validating and adjusting results. For example, suppose an event is geo-tagged to associate it to a geographic location, and the event is described in an article about Montevideo news from Uruguayan newspapers collections. In that case, a human will verify that the geographic location refers to Montevideo in Uruguay and not in the US.

Fig. 1. Event Data Model
The event knowledge model provides concepts for representing a meteorological event according to the perspectives. Each aspect addressed by the knowledge model is implemented using different data structures with associated operations to support exploration actions. The following lines describe the different perspectives associated with an event and represented by the event model: descriptive, meteorologic, linguistic and knowledge domain profiles.

**Descriptive profile** There is not a generic list of attributes used for describing a climatologic event in newspapers articles. Indeed, meteorological events are described in different ways in historical newspapers articles, depending on the author. However, we can often collect information related to location, date, duration, scope, and damages. Meteorological features (like millimetres of precipitations, wind speed, temperature, pressure, etc.) can be explicitly described in articles or deduced according to the description of the event. For example, an event reported in Montevideo and describing an overflow of the river implies winds higher than 100 km/h and rain of more than 10 ml/hour, according to the knowledge provided by meteorologists. This knowledge domain is used for completing the meteorologic features describing the reported event.

**Linguistic perspective** gathers the terms used for describing an event in one or several articles belonging to a given newspaper. We propose a tree-based data structure, named *content tree* for representing the content of a historical newspaper article. (see the UML class diagram in Figure 2). The tree corresponds to the grammatical analysis of each sentence in the textual content of the article commonly used in Natural Language Processing (NLP) techniques. The *content tree*, as shown below, consists of a set of sentences. A *sentence* is defined as a set of nodes representing grammatical elements of a sentence and leaves representing the terms composing a sentence in a specific article.

![UML class diagram representing the general structure of a content tree](image)

As shown in Figure 2 a **node** represents a type of grammatical element given in a specific linguistic model defined for a specific language. It is labelled adopting the entity labels produced by classic natural language processing tools known as Part Of Speech (POS) tags. For instance, *noun, proper singular* (NNP),
noun, plural (NNS), verb, modal auxiliary (MD), Geopolitical entity (GPE), or Organization. In the case of subjects (NNP), they can be grouped into more general entities that identify geographic locations (GPE), places, names, and organization

A node has a child, which is also a Node or a Leaf, and a set of siblings, which are other nodes. A leaf specializes a node, and it represents a term contained in the article. A term is a string and has a parent, a node represents a POS tag.

Every article in a newspaper is associated with its content tree. Thereby, a data analyst or expert domain can explore the articles by navigating their content trees without reading the full content. For example, retrieve articles reporting heavy storms in Uruguay in December 1810.

Meteorological perspective characterizes the event with attributes used to describe it in one or several newspaper articles. Nevertheless, not all the attributes can necessarily have a value since there might not be any evidence within the articles that report it. Attributes, like the date of the event, its geographical scope, or the location of the damaged regions, are computed by navigating through the content tree of every article reporting the event.

ClimateEvent: <date: Data, duration: <init:Date, end:Date>
scope:{<locationName: String, long: Float, lat: Float>}
name: String, damages: {String}>

Knowledge domain perspective describes meteorological events using knowledge domain statements created by experts of the National Library of Uruguay. This knowledge has been associated with events through manual analysis of newspapers collections and interacting with meteorologists. This knowledge can help interpret the empirical information reported in the articles and complete the information associated with the event description. For example, if the river was flooding due to a storm, it is possible to estimate the wind speed and the approximate litters of rain. The knowledge domain perspective is modelled as a glossary.

2.1 Building a climatologic event history

Given a documents’ collection and its associated data structures describing the content of its articles, the data scientist can explore articles to determine whether they report climatologic events. This phase integrates the human-in-the-loop. The reason is that newspaper articles’ use of colloquial terms can be tricky and refer to metaphors that might not denote a climatologic event. Language subtilities are not easy to handle manually, mainly because we are dealing with a language used some centuries ago, which increases the challenge of classifying the content of the articles. During this phase, articles referring to climatologic events are geo-temporally tagged to associate them with the region and/or time

5 A full list of POS tags can be found in https://www.cms.gov/
window in which they happened. Tags are validated by the data analyst. Since the result can contain a significant number of articles, the user can use three tools for understanding the content of the result. The tools let her manipulate a terms frequency matrix, a terms heat map. She can also explore the content of the article text using a view that provides information about the context in which the terms potentially describing an event appear in the document. For example, the name of geographic locations in the document might refer to the location of the event and the region that it touched, and a list of geopolitical entities (e.g., school, public building, etc.) to determine the damages caused by the event.

The data analyst can perform the following actions:
- Correct the terms associated with climatologic events that might not be used in such a sense in the text. Indeed, some social and political demonstrations are often described as climatologic events. For a classic automatic text analysis process, this can be not easy to identify and filter. For example, an article entitled Stormy weather within the ails of the senate in Ecuador has nothing to do with a climatologic event but with a political one.
- Determine whether personal names correspond to the event’s name (e.g. hurricane or storm name). If that is the case, this information will be used for inserting the event in the history.
- Verify whether the names of cities, regions and countries correspond to geographic entities. The system underlines the names of patronyms, and the data analyst can see the location of the possible geographic entities. Thus, the user can also confirm whether the article refers to the geographic zone that she is searching for. For instance, if "Santa Clara" is underlined, it can refer to a place, city, or village.
- Determine the date of the event and its characteristics. The temporal terms and adjectives are also underlined to let the data analyst click on those that describe the event.
- Determine the type of damages caused by the event by exploring those terms that describe such kind of information.

The previous actions are used to adjust the representation of the articles’ content and identify meteorological events more accurately since the data analyst or domain expert knowledge is used (see Figure 3 showing LACLICHEV interfaces for curation).

2.2 Climatologic Events History

Once the events have been validated, the data scientist can use a form to define and store the event. Meta-data is stored in persistence support, a key-value or a document store depending on the technology adopted by each library, whereas the raw documents remain archived in a different server or the same store. The climatologic event’s history provides an interface for performing querying and analytics tasks on top of it. For example, locate events that happened during the XIX century, enumerate and locate the most famous climatological events
in the region, create a heat map of the events in Latin America that happened in the last ten years of the XIX century.

2.3 Exploring the collections of digital newspapers

Newspaper articles are explored by conjunctive or disjunctive keyword queries, where keywords can belong to several vocabularies. For example, search articles reporting heavy storms and rivers flooding. The query expressed by a data analyst is automatically completed by using rewriting techniques that consider synonyms, more specific or more general concepts [4]. Thus, three tools can be used for exploring meteorological events depending on expert knowledge of what she/he is looking for:

- Filtering. Retrieving factual information. For example, filtering events by region or country or by year. For example, Uruguay for the country and between 1800–1810 for the temporal filter.

- Term frequency. Understanding the content of digital newspaper collection through the vocabulary used in its articles. Therefore, LACLICHEV exposes the terms frequency matrix and a terms heat map under an interactive interface. The domain expert can see which are, statistically, the terms most used in the articles, group documents according to the terms used, choose articles using a specific term.

- Additional information. Exploring the content of a specific article using a view that provides information about the name of geographic locations in the document that might refer to the location of the event and the region that it touched, and a list of geospatial features (e.g., school, public building, etc.) to determine, for example, the damages caused by the event.
3 LACLICHEV in action

We have implemented LACLICHEV, a data collection exploration environment accessible as a Jupyter notebook. It is a client-server system that uses the platform Jupyter for executing the human-in-the-loop tasks that implement the data exploration process. Figure 4 shows the general architecture of LACLICHEV organised into three layers: (i) frontend giving access to the event history containing curated articles reporting climatologic events and providing tools for curating articles and creating events descriptions; (ii) backend with the climatologic event history and tools for pre-processing newspaper articles; (iii) external layer connecting to documents providers that are available through servers accessible in the web and through APIs exported by libraries.

![Diagram of LACLICHEV architecture](image)

**Fig. 4.** General functional architecture of LACLICHEV

3.1 Building a Latin American climatologic event history

We have worked with the national libraries of Mexico, Colombia, Ecuador and Uruguay to access their newspapers digital collections. For our experiments, we worked with the collections of the XVIII and XIX centuries of newspapers written in Spanish with the linguistic variations of three countries Mexico, Colombia, Ecuador and Uruguay.

We curated collections and generated the vocabulary used on articles identified as reporting a meteorological event. Digital newspaper collections remain in the initial repositories that belong to the libraries. Then, terms and links to the OCR (Optical Character Recognition) archives containing documents with
articles reporting meteorological events were stored in distributed histories managed in each country. As shown in Figure 5, the process consists of five steps usually used in natural language processing techniques: sentence segmentation, tokenization, speech tagging, entity and relation detection. LACLICHEV implements these phases on Python, relying on the NLTK library.

Besides curating the data collections content, we wanted to discover linguistic variations in different Latin American countries to describe meteorological events. People’s language and variations can picture civilians’ perception of these events, consequences, and associated explanations. Thus, local vocabularies were created out of the terms used in newspapers’ articles (see Figure 6). For example, referring to a storm as a stormtrooper In Mexico a storm is called a "chaparrón" and in Uruguay it is called a "chubasco". Then we updated and enriched through queries, exploration and analytic activities these vocabularies through human-in-the-loop actions. Data analysts tagged "colloquial" terms used to describe climatologic events and associated them with more scientific terms. These terms can be then used for defining keyword queries for exploring newspapers datasets.

3.2 Querying, exploring and curating data collections
LACLICHEV proposes a frontend for data scientists to:
- Query the event’s history of already tagged events. The queries can be keyword oriented (e.g. locate the most famous events in Mexico during the XvIII century). Users decide to use some terms that can belong to any of the vocabularies generated in the pre-processing phase. LACLICHEV applies then query rewriting techniques to extended user expressed queries with synonyms, subsuming and general terms. The particular characteristic of this task is that the user (i.e., data analyst) can interact and guide the process according to her/his knowledge and expectations about what she/he expects to explore and search.
- Perform analytics operations and analyse results are generally presented within maps (e.g. how did rainy periods evolved in the region?). In the current version of LACLICHEV analytics queries cannot be expressed in the frontend. They are implemented manually through notebooks running on top of the event history.
- Exploring data collections for curating them and building the history of climate events.
- Manage vocabularies, adding terms, guiding their classification and studying the linguistic connections between the terms used in the different countries.

Data analysts can express queries that can potentially explore historical newspapers content to find articles describing meteorological events. The aim is to have a good balance between precision and recall despite the ambiguity of the language (Spanish variations in naming climate events). The domain experts must express "clever" queries that can exploit the collections to achieve this goal.

Queries can be initial conjunctive and disjunctive expression combining terms chosen from the built-in vocabularies or not. Then, queries are rewritten in an expression tree where nodes are conjunction and disjunction operators and leaves are terms, according to an input query expressed as a conjunction and disjunction of terms potentially belonging to a meteorological vocabulary. Our approach for rewriting queries is based on a "queries as an answer" process. This technique rewrites user queries into queries that can produce more precise results according to the explored dataset content. Queries as answers proposed by LACLICHEV consists of a list of frequently used queries. Thus, we focus on the following aspects:

*Extending query alternatives using hypernyms and synonyms* Given an initial conjunctive/disjunctive query is rewritten by extending it with general and more specific terms, synonyms, etc. The terms used to express the query belong to colloquial vocabulary for denoting meteorological events. The rewriting process can be automatic or interactive, in which case the system proposes alternatives...
and the user can validate the proposed terms. For example, if the query is "heavy storms", the query can be completed by adding "heavy stormtrooper", "heavy storm dust".

We use Wordnet\footnote{http://timm.ujaen.es/recursos/spanish-wordnet-3-0/} for looking for associated terms and synonyms that help address concepts used in different Spanish speaking countries. We do not translate the query terms to other languages because our digital data collections consist of newspapers written in Spanish. LACLICHEV allows equivalent terms searching to morph a query. For a new term, LACLICHEV generates a node with the operator and then connects the initial term with the equivalent terms in a disjunctive expression subtree. Thereby, more general terms are collected and connected to the initial term with these terms in a conjunctive expression subtree. The result is a new expression tree corresponding to an extended query $Q_{Ext}$. The query morphing algorithm behind LACLICHEV is described in [8].

**Extending query alternatives using cultural terms** Use local vocabularies for generating new query expression trees that substitute the terms used in $Q'_{Ext1}$ with equivalent terms used in a target country (e.g., blizzard instead of a heavy storm). This will result in transformed expression trees each one using the terms of a country ($Q'_{Ext1 ... Q'_{Extj}}$) \[9\].

A series of what we call "folksonomies" in a metaphorical way, which are vocabularies created through the processing of the vocabulary of newspaper articles. We create and feed each vocabulary according to the country of origin of the processed newspaper article. This lets us extract the vocabulary used during the XVIII and XIX centuries for describing meteorological events in different Latin American countries (i.e. Mexico, Colombia, Ecuador, and Uruguay). Using this information LACLICHEV can answer the following queries: *How have terms used to describe climatological events changed between XIX–XX c.?* *Which are standard terms used to describe climatological events across Latin American countries?* *Which is the distance between terms used in XIX–XX c.?* *Which are the most popular terms used in XIX c. for describing climatological events?*

**Defining filters using knowledge domain** We also use domain knowledge for rewriting the queries. We have a knowledge base provided by domain experts that contains some meteorological event rules. For example, rules state that in the presence of a heavy storm: R1. the wind speed is higher that 118 km/hr; R2. the rivers can grow and produce big waves; R3. there are rains between 2.5 7.5 mm/hr; R4. the range of surface that can be reached by a 100 km wind speed storm is of 1000 km.

Our approach uses this information for generating possible queries that help the domain expert better precise her/his query or define several queries that can be representative of what she/he is looking for. For example, the previous initial query "$Q_1$: heavy storm" is rewritten into new additional queries: "$Q_{11}$: heavy storm or storm with wind speed > 100 km" (using R1). "$Q_{12}$: storms with 100 km speed that reached Mexico City" (using R2 and knowing the initial
 Analytics queries The climatological event’s history provided and maintained by LACLICHEV can visualize information and perform analytical tasks. For example, LACLICHEV can answer spatio-temporal queries like: Q1 Locate climatologic events in the XVII c., Q2 Enumerate & locate the most famous events in the region and Q3 Create a heat map of events in LATAM in the last years of the XIX c. The objective is to answer analytics queries that imply aggregating information stored in the event’s history. For example, How did rainy time evolve in time in the region? In which way was climate different between XVII and XIX c.? How did vocabulary evolve from colloquial to scientific and standardized in the XX c.? In future versions, LACLICHEV is willing to answer prediction queries like Could it have been possible to predict the evolution of climate behaviour from the data in XVIII and XIX c.? This type of queries requires the collection, curation and preparation of more newspapers articles and other complementary data. This concerns future work.

4 Related work

The emergence of the notion of data exploration provides different perspectives of the data and tools for helping data scientists choose and compound datasets adapted for target experiments [6].

Despite the availability of datasets, very often, users are unsure which patterns they want to find. Data exploration [6] addresses this requirement and proposes strategies for going into the whole or samples of datasets to understand their content for determining the type of questions they can answer. Some of the techniques used for fulfilling this particular requirement are data grooming, multi-scale queries, result set post-processing, query morphing, and queries as answers. Data grooming denotes the process of transforming raw data into analysable data with various data structures. Multi-scale queries propose to split a query into multiple queries executed on different fragments of the database and then perform a union of those queries. Result set post-processing assumes an array of simple statistical information such as min, max, and mean to be more helpful, especially on massive data sets. Query morphing and queries as an answer are rewriting techniques that compute alternative queries (e.g., adding terms) that can potentially better explore a dataset than an initial query. Approaches such as interactive query expansion (IQE) [7,13] have shown the importance of data consumers in the data exploration process. Users’ intention helps to navigate through the unknown data, formulate queries and find the desired information. In most of the occurrences, user feedback acts as vital relevance criteria for next query search iteration.

Existing solutions are not delivered in integrated environments that data analysts can comfortably use to explore data collections. The technical effort is
still necessary to combine several tools to explore and process datasets and go from raw independent data sets to knowledge, for example, on climate change. Therefore, LACLICHEV aimed to tailor a data exploration environment that could help explore digital datasets using a human-in-the-loop approach.

5 Conclusion and Future Work

This paper presented our approach for exploring newspaper digital collections for building knowledge about the history of climate change in Latin America. Using well-known information retrieval and analytics techniques, we developed a data exploration environment that provides tools for understanding the content of collections. Rather than directly querying collections for searching documents or performing data analytics operations (statistics, correlations), the objective is to let data scientists understand the content of the collections and then decide what kind of queries to ask. We used digital newspapers collections for applying such techniques for building and analyzing the history of climate change in Mexico, Colombia, Ecuador and Uruguay. The work reported here is the first step towards this ambitious challenge. We continue enriching data collections, developing and testing solutions for generating and sharing step by step this history.

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