Event Timeline Generation from History Textbooks

Harsimran Bedi[a]* **Sangameshwar Patil**[b] **Swapnil Hingmire**[b] **Girish K. Palshikar**[b]
{bedi.harsimran, sangameshwar.patil}@tcs.com
{swapnil.hingmire, gk.palshikar}@tcs.com
[a]Department of CSE, IIT Patna, India
[b]TCS Research, Pune, India

Abstract

Event timeline serves as the basic structure of history, and it is used as a disposition of key phenomena in studying history as a subject in secondary school. In order to enable a student to understand a historical phenomenon as a series of connected events, we present a system for automatic event timeline generation from history textbooks. Additionally, we propose Message Sequence Chart (MSC) and time-map based visualization techniques to visualize an event timeline. We also identify key computational challenges in developing natural language processing based applications for history textbooks.

1 Introduction

With the advent of easy access to on-line educational content on the Internet through mobile and electronic reading devices, there is increasing trend of e-learning and hence creating resources that support e-learning. An important advantage of e-learning is it enables learners to do "any time, any place, any pace" learning (California Department of Education, 2012; Agrawal et al., 2013).

In this paper, we particularly focus on creating event timeline (or chronology) from history textbooks. Event timelines play an important role in understanding a historical phenomenon. It enables a student to situate her knowledge of history in relation to a spatio-temporal context.

De Keyser and Vandepitte (1998) identify different frames of reference that play a vital role in a student's understanding of a historical phenomenon:

1. *Chronological frame of reference*, which focuses on key phenomena and their significance over a period of time (e.g. key events in the *Renaissance*).

2. *Spatial frame of reference*, which focuses on key locations, geographies involved in the phenomenon (e.g., spread of the *Renaissance* across various parts of Europe)

3. *Social frame of reference*, which focuses on how the social fields such as politics, economics, culture, etc. interact within society during the phenomenon (e.g., social, cultural, religious characteristics of the *Renaissance*).

Stow and Haydn (2000) highlight importance of these frames of reference to develop a student's ability to ask and answer questions like "When did a particular phenomenon happen? What is its relevance to the present and the future? What are the key insights of it that should be learned?"

In this paper we primarily focus on the *Chronological* and *Spatial* frames of reference. We believe that it will also serve as a building block for the *Social* frame of reference. In this paper, we present a system for automatic event timeline generation from history textbooks. In addition to event timeline creation, we also propose two techniques for visualization of a timeline. The first technique uses Message Sequence Chart (MSC) (Rudolph et al., 1996) to highlight the interaction between multiple entities associated with a historical phenomenon. In the second technique, we first associate each event in a timeline with a time marker, a location, and one or more actors, and create a time-map to capture a spatio-temporal aspect of the timeline. An additional important goal of this paper is to identify key research problems in developing natural

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language processing based applications for history textbooks.

The paper is organized as: in Section 2 we give an overview of related work on timeline generation from a different type of text resources. In Section 3 we highlight important use-cases of event timelines. In Section 4 we propose our algorithm for timeline generation. Section 5 discusses two techniques for visualization of timelines. Experimental evaluation of generated timelines is an active area of research. In Section 6 we present preliminary results on validation of events having mention of time expressions. Section 7 discusses computational challenges in the construction of event timeline from NLP perspective. In Section 8 we conclude and discuss prospects of our work.

2 Related Work

Several authors (e.g. (Bamman and Smith, 2014; Palmero Aprosio and Tonelli, 2015; Ge et al., 2015)) have proposed use of encyclopaedic resources like Wikipedia in event time-line construction of historical figures and events. It is important to note that Wikipedia articles give a comprehensive overview of a historical phenomenon and try to cover all facts with hyperlinks and references to relevant material. Also, each Wikipedia article is focussed on one phenomenon, and it is likely to be authored independently of Wikipedia articles that it hyperlinks. So, it is highly possible that the authors of a Wikipedia article may assume that the reader has knowledge about other Wikipedia articles that it hyperlinks. This encyclopedic rigor may not be necessary for primary or secondary students, and such bombardment of facts may not encourage a student to obtain an interest in history. On the other hand, content in the textbooks is organized such that each section or chapter is focused on one concept and concepts are progressively introduced with specific learning goals (Agrawal et al., 2012).

Apart from Wikipedia, several authors have constructed timelines from social media like Twitter (e.g. (Alonso et al., 2017; Yao et al., 2016; Li and Cardie, 2014)) or news articles (e.g. (Zhou et al., 2016)). However, social media or news articles are not intended to be consumed by history students.

3 Use-Cases for Event Timeline for History Text

We identify following use-cases for event timelines from history text:

1. **Comparison of Timelines:**
   a) We can use timelines of two entities (e.g. kings or emperors) to understand similarity and differences between their lives. For example, a student or a historian would like to compare timelines of rulers who achieved power on their own at a young age, e.g., *Napoleon* and *Shivaji*[1]. The similarities in their lives as well as rise to power can be easily seen from their timelines e.g., both received military training early in their childhood. Both assumed leadership roles at a very young age. Napolean was officer at 16. Shivaji conquered the Torna fort and laid foundations of his kingdom at age of 15. They scored remarkable victories in their twenties. Napolean became Master of France at 30; whereas by age of 30, Shivaji, though not formally a king, had already established his rule over vast land of present day Maharashtra state of India. Both died in their early 50s.
   b) Timelines of two different dynasties or empires also can be used to compare their rise and fall (e.g., *First French empire* vs *Second French empire*).
   c) Comparison of timelines can be extended beyond entities such as kings or empires. For example, a student may be interested in comparison of two different civilizations e.g., the *Roman civilization* vs. the *Indus valley civilization*.

2. **Causal Analysis of Events:** Using textual clues and text entailment techniques from NLP combined with ordering of events from timeline can be used to infer causes or conditions that led to an event or a sequence of events: e.g., seeds of *World War II* were already sown at the end of *World War I*. Such a causal analysis can also be used for comparison of two event timelines. For example, *The Great Depression*[2] and *The Great Reces-*

[1] https://en.wikipedia.org/wiki/Shivaji
[2] https://en.wikipedia.org/wiki/Great_Depression

sion[3] are two major economic events that affected the world population. One would like to analyze the timelines of these two events and understand common or different causes of different events and their social, political, economic consequences.

3. **Pedagogical Applications:** We believe that event timelines and their formal representations can be used for creating pedagogical resources that will be useful for students as well as teachers of history. For example, students can use event timelines for question answering while teachers can use them for automatic question generation as well as automatic answer evaluation.

Developing solutions to the use-cases discussed above is part of future work. Our current focus is to (a) automatically generate event timelines using NLP tools and techniques, (b) develop solutions to visualize timelines that would help student to understand history using succinct representations.

4 Our Method

In this section, we give details of our proposed system.

4.1 Event Description

Defining an event for our system is crucial to our task. For the purpose of history textbooks, an event can be thought of an important thing that happened or took place at a certain point of time. It changed something or had some definite consequences in the physical world. For the purpose of this paper, we consider those events which are described by a verb. Verbs like *die, kill, defeat* are absolute physical action verbs giving a clear indication that something important happened. On the other hand, verbs like *consider, regard, think* are related with a psychological or mental action that did not happen in real. In this paper, we assume that an event represents an *activity, accomplishment, achievement, and change in physical state* (Vendler, 1957, 1967; Casati and Varzi, 2015).

4.2 Dataset Creation

To create a gold standard dataset, we annotated portions from following two history books – (i) *Chapter 5: Consolidation and Expansion of the Empire - Akbar* (77 sentences) in *Medieval India: From the Sultanate to the Mughals* (Chandra, 2007) and (ii) *Chapter 23.3: Napoleon forges an empire* (113 sentences) from the book *World History* (Harker, 2012). The schema used for annotation is briefly described in Table 1. For every event, the schema consists of title, actors, locations, time/date expressions, and event description.

- `event title` (E_T) := title of the event, a succinct phrase capturing the gist of the event
- `actor i` (A_i `for` $i = 0, 1, \ldots, n$) := actors mentioned in the sentence
  - `actor type` (A_T) = {`person, organization`} := whether the actor is a person or an organization (e.g. *allies of World War II*[4] can be treated as an organization)
- `event time expression` (T) := the fragment of the sentence that represents temporal expression of the event
  - `time expression modifier` (T_M) = {`after, before, during, beginning, end, early, late`}
  - `time expression type` (T_T) = {`date, time, duration`}
- `location` (L) := the location at which the event happened
- `event verb phrase` (E_{VP}) := the verb phrase of the sentence that represents the event.

Table 1: Annotation Schema

Table 2 gives annotation of a few example sentences from (Chandra, 2007, Chapter 5).

4.3 Event Timeline Generation

The algorithm (Table 3) has three main steps. First, we extract the named entities in the text using Stanford CoreNLP (Manning et al., 2014). The PERSON and ORGANIZATION type named entities form the set of actors. The LOCATION entities give us spatial information about the events. Then we resolve the co-references of these entities. In the second step, we use SUTime temporal expression tagger (Chang and Manning, 2012) to extract the temporal expressions from the sentences having the mentions of actors or locations.

Our current system considers only those sentences for creating a timeline which contain at least one temporal expression. We name these sentence as "timeline sentences". We also provide facility to create an actor specific timeline genera-

[3] https://en.wikipedia.org/wiki/Great_Recession

ID	Sentence	Event title (E_T)
S_1	[Early in 1576]$_T$, [Akbar]$_{A_0}$ [moved to]$_{E_{VP}}$ [Ajmer]$_L$.	*Akbar moved to Ajmer*
S_2	[Akbar]$_{A_0}$ [deputed]$_{E_{VP}}$ [Raja Man Singh]$_{A_1}$ with a force of 5000 consisting of [Mughals]$_{A_2}$ and [Rajputs]$_{A_3}$ to lead a campaign against [Rana Pratap]$_{A_4}$.	*Akbar deputed Raja Man Singh against Rana Pratap*
S_3	In anticipation of such a move, [the Rana]$_{A_0}$ had [devastated the entire region]$_{E_{VP}}$ upto [Chittor]$_L$ so that [the Mughal forces]$_{A_1}$ could get no food or fodder.	*Rana Pratap devastated the entire region upto Chittor*
S_4	[The Rana]$_{A_0}$ [advanced with a force of 3000]$_{E_{VP}}$ from his capital at [Kumbhalgarh]$_L$.	*Rana Pratap advanced from his capital at Kumbhalgarh*
S_5	[The Rana]$_{A_0}$ [took a position]$_{E_{VP}}$ near [Haldighati]$_L$, at the entrance of the defile leading to [Kumbhalgarh]$_L$.	*Rana Pratap took a position near Haldighati*

Table 2: Annotation of a few example sentences from (Chandra, 2007, Chapter 5)

tion. Given an actor, we filter those timeline sentences that mention the actor or have co-reference to the actor. In addition to named entities, we identify relations mentioned in a sentence using OpenIE component of Stanford CoreNLP (Angeli et al., 2015). We select the relation which has mentions of the maximum of a number of named entities as the title of the sentence. The algorithm for generating event timeline from a given piece of text is given in Table 3.

- **Input:** Chapter or Section of a history textbook : $\mathcal{C}$
- **Output:** Event timeline : $\mathcal{T} : \{e_1 \prec e_2 \prec e_3 \prec \ldots \prec e_N\}$, where $e_i =<$event title (E_T), actors (A), time expressions (T), location (L) $>$
- **Entity Extraction:**
  1. Identify named entities (e.g., person, organization, location) in each sentence in $\mathcal{C}$.
  2. Resolve the co-references of entity mentions.
  3. Extract set of sentences S which refer to these named entities from $\mathcal{C}$.
- **Time-Expression Extraction:**
  - Identify time expressions in each sentence in S.
- **Timeline Generation:**
  1. Let $S' \subseteq S$ such that each sentence in S' contains at least one time expression and at least an actor.
  2. Let $\mathcal{T}$ be initialized to empty timline.
  3. For each sentence $s \in S'$:
     (a) Let $A = \{A_0, A_1, \ldots, A_K\}$ be the list of actors mentioned in s
     (b) Let L = the location mentioned in s. (if no location mention in s, L = NULL)
     (c) Let T = the time expressions mentioned in the sentence
     (d) Identify relations between entities in s using OpenIE component of Stanford CoreNLP and select the relation with maximum number of named entities as title of the event (E_T)
     (e) Append tuple $e =< E_T, A, T, L >$ to $\mathcal{T}$
  4. Print event timeline $\mathcal{T}$.

Table 3: Algorithm for Timeline Generation

5 Visualization

Visualization of a timeline to promote better learning and understanding of students is highly relevant to this task. Features of a timeline like the flow of the events, the temporal and spatial elements of an event should be evidently clear in the visual output. We propose two techniques for visualization of a timeline.

5.1 Message Sequence Chart (MSC)

MSC is widely used for the visualization of message interchange of communicating entities with a communication system (Rudolph et al., 1996). An important goal of MSC is to do a visual abstraction of causal relations between events and participation of different entities within a communication system in these events. The diagram area of MSC involves two dimensions: vertical and horizontal. The vertical dimension represents time while the horizontal dimension represents entities.

It is important to note that a historical phenomenon is comprised of various entities (e.g., persons or organizations) and a set of ordered events. Hence, we believe that MSC can be used to visualize the timeline of a historical phenomenon such that the vertical or time dimension captures order of events that happened over a period, while the horizontal or entity dimension represents entities involved in these events. Currently, we manually create MSCs explicitly specifying the entities and the events. A sample MSC created using a MSC generator tool[5] for a sequence of events is shown in Figure 1. Following text from (Harker, 2012) was used while generating the MSC:

"*In only four years, from 1795 to 1799, Napoleon rose from a relatively obscure position as an officer in the French army to become master of France. Napoleon Bonaparte was born in 1769*

[5] https://www.websequencediagrams.com/

on the Mediterranean island of Corsica. When he was nine years old, his parents sent him to a military school. In 1785 , at the age of 16, he finished school and became a lieutenant in the artillery. When the Revolution broke out, Napoleon joined the army of the new government. In October 1795, fate handed the young officer a chance for glory."

In future, we would use APIs of the library to generate MSCs automatically.

5.2 Timeline with a Map (TimeMap)

As discussed earlier, the *spatial frame of reference* is important in a student's understanding of a historical phenomenon. Hence, towards the goal of enabling a student to realize the importance of geographical conditions of the location at which an event happened we propose a map based visualization system. For example, consider the following text from (Chandra, 2007, Chapter 5): *The battle of Haldighati (18 Feb. 1576) was mainly fought in the traditional manner between cavalrymen and elephants, since the Mughals found it difficult to transport any artillery, except light artillery over the rough terrain.*

It is important to note that *Haldighati* is a mountain pass in western India[6] and its geographical characteristics played a vital role in the *The battle of Haldighati*[7]. The example is illustrative in the sense that it emphasizes both temporal and spatial aspects in understanding the event: *The battle of Haldighati*.

We generate a time map for a given event timeline using *TimeMapper*[8]. The time map generated by TimeMapper can be embedded in an HTML page and can be easily viewed using a browser. For each event in a timeline we show its title, description and temporal expression and if the location of the event is available, then it is shown on the map. The events in a timeline can be browsed in sequential or random order by clicking on an event in the timeline. A sample event of a timeline can be seen in Figure 2.

6 Experimental Evaluation

Experimental evaluation of generated timelines is an active area of research. As mentioned earlier, in this paper, we focus only on the sentences having mention of time expression. For the task of timeline generation, sentences with the time expressions are important as they enable relative ordering of events.

For the evaluation, we use the annotated portion from Chapter 5 (*Consolidation and Expansion of the Empire - Akbar*) from (Chandra, 2007). The dataset contains total 77 sentences having 1771 words. These sentences are linguistically complex. There are 22 words on average per sentence. Out of the 77 sentences, 27 sentences contain events with time expression. For the event detection task, the proposed algorithm achieves precision, recall and F1-measure of 0.647, 0.407 and 0.500 respectively.

We note here that this is a preliminary evaluation because we are considering only those events which are described by verbs. Further we have not tackled relative ordering of implicit time expression. For a more comprehensive generation and evaluation of event timelines, we need to address these and the other challenges identified in the Section 7. We recognize a more rigorous treatment for the same as a significant direction for future work.

7 Computational Challenges in Timeline Generation

The inherent nature of historical events along with its narration pose some specific challenges from NLP viewpoint. We incurred these challenges while annotating the data set and comparing it with the results obtained from our system. They are listed below:

7.1 Implicit temporal mentions and temporal co-reference

There are cases when a period is given but not in an explicit manner. In Table 4:R-1 we can observe that `the next twelve years` and `this period` refer to the time period of `1585-1592`. To place the corresponding event(s) on the timeline one needs to accurately resolve the explicit mention of `1585` to the above co-referring implicit time expressions.

7.2 Entity co-reference resolution

Co-reference resolution of entities (e.g., Person, Location, Organization) is a well-studied problem in NLP literature. In our proposed algorithm, we

[6] https://en.wikipedia.org/wiki/Haldighati

[7] https://en.wikipedia.org/wiki/Battle_of_Haldighati

[8] http://timemapper.okfnlabs.org/

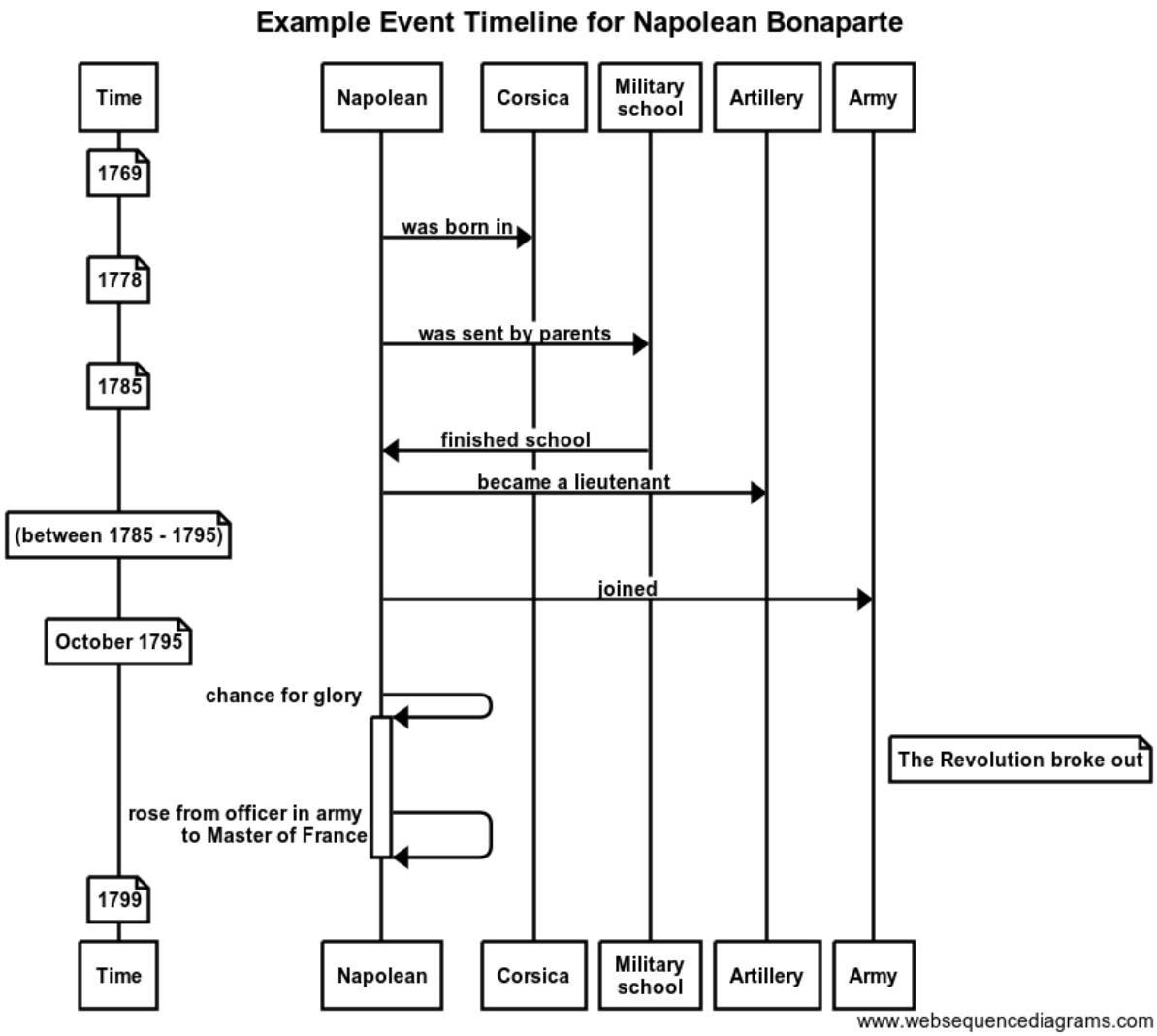

Figure 1: Multi-actor interaction visualization using Message Sequence Chart

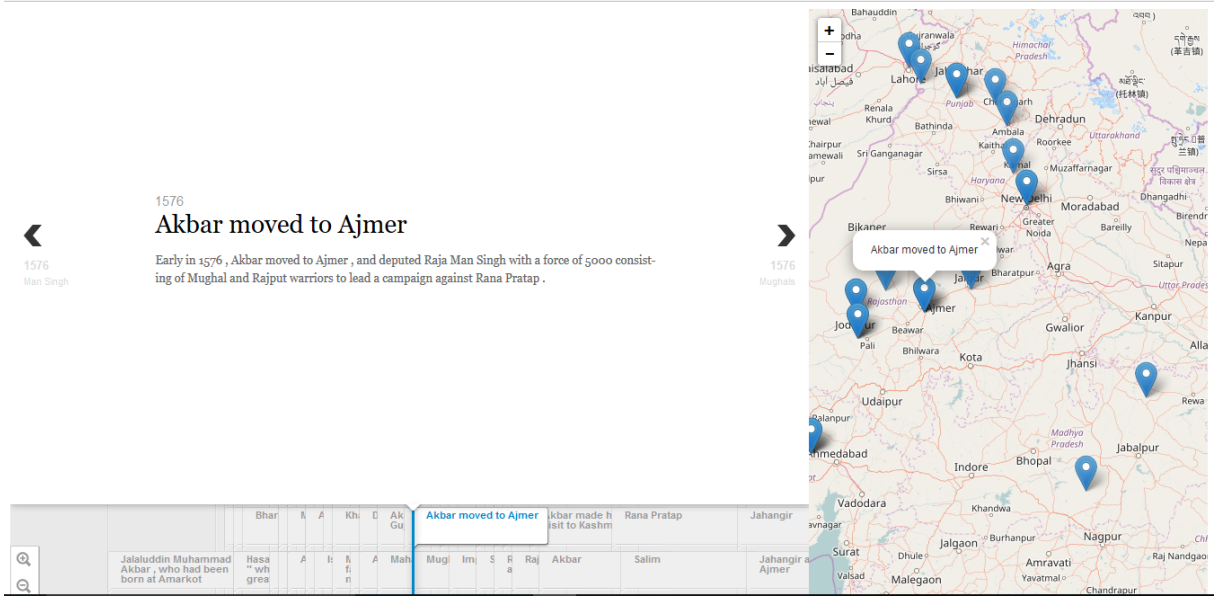

Figure 2: Sample screenshot of Time Map (spatio-temporal) corresponding to Table 1:S_1 sentence

R-1	**Implicit temporal mentions**	In 1585, Akbar moved to Lahore, and remained there for [the next twelve years], watching the situation in the north-west. No Mughal expedition was sent against Rana Pratap during [this period].
R-2	**Event coreference resolution**	Prince Salim was [sent against]$_{E1}$ the Rana in 1599, but achieved little. He was again deputed for [the purpose]$_{E1}$ in 1603, but he had no heart in [the enterprise]$_{E1}$. After his accession, Jahangir took up [the matter]$_{E1}$ more energetically.
R-3	**Inaccuracy due to wrong Entity coreference resolution**	[Sagar]$_{P1}$, [the son of Rana Udai Singh]$_{P1}$, [who]$_{P1}$ had joined [Akbar]$_{P2}$, during the rule of [Rana Pratap]$_{P3}$, and granted the title of Rana and installed at Chittor by [Jahangir]$_{P4}$, was set aside, and all the paraganas of Mewar, including Chittor were restored to [Rana Amar Singh]$_{P5}$.
R-4	**Normalization of named entities**	[He]$_{P1}$ died in 1597 at the young age of 51, due to an internal injury incurred by him while trying to draw a stiff bow. ... [Prince Salim]$_{P2}$ was sent against [the Rana]$_{P1}$ in 1599, but achieved little. [He]$_{P2}$ was again deputed for the purpose in 1603, but [he]$_{P2}$ had no heart in the enterprise. After [his]$_{P2}$ accession, [Jahangir]$_{P2}$ took up the matter more energetically.
R-5	**Hierarchy of events**	Sagar, the son of Rana Udai Singh, who had joined Akbar, during the rule of Rana Pratap, and granted the title of Rana and installed at Chittor by Jahangir, was set aside, and all the paraganas of Mewar, including Chittor were restored to the Rana.
R-6	**Location as an actor**	At the time of Napoleon's coup, France was still at war. In 1799, [Britain, Austria, and Russia] joined forces with one goal in mind, to drive Napoleon from power.

Table 4: Examples of computational challenges from NLP perspective faced while processing of history text

use entity-centric co-reference annotator component of Stanford CoreNLP (Clark and Manning, 2015).

In Table 4:R-3, we see the gold-standard coreferences for a sample sentence. The state-of-the-art Stanford CoreNLP coreference algorithm is not able to identify any of the gold-standard coreferences and incorrectly identifies a coreference between the phrases Rana Pratap and Rana (in the phrase "title of Rana"). For timeline generation task these errors in co-reference resolution have a cascading effect on the accuracy of actor, location identification etc. This results in incorrect events participants on the timeline.

7.3 Event co-reference resolution

Apart from the person/entity level co-reference resolution, history text poses very interesting co-reference resolution challenges at event level. In Table 4:R-2, sent against is an event involving two entities Prince Salim and the Rana. This event (*E1*) is referred to as the purpose, the enterprise, the matter in the subsequent lines.

7.4 Normalization of entity names

In the historical domain, a person of importance has many names or titles throughout his/her lifetime.

- **Title resolution:** With reference to the Rajputs[9], *The Rana* was a standard epithet given to the current heir of the Rajput dynasty. In (Chandra, 2007, Chapter 5), initially the title the Rana is used to refer to Rana Pratap Singh. Further in the chapter his son Rana Amar Singh is referred to by the same title. In Table 4:R-4, He and the Rana refer to Rana Pratap according to the output of Stanford CoreNLP Co-Reference Annotator. But in real, the Rana refers to Rana Amar Singh.

- **Multiple names to same person:** Another case of this challenge arises when two names are used for the same person like *Jahangir*[10] is also referred to as *Prince Salim*.

- **Location standardization:** The problem of standardization is also applicable to locations. Cities or states names mentioned in history might have been replaced with new names at present. This poses a problem when it comes to locating that place on a map. For

[9] https://en.wikipedia.org/wiki/Rajput
[10] https://en.wikipedia.org/wiki/Jahangir

example the state of *Mewat*[11] mentioned in (Chandra, 2007, Chapter 5) does not exist on India's map.

7.5 Hierarchy of events

The task of event extraction is a complicated one. In simple sentences the event verb and its arguments are clear. But if we look at Table 4:R-5, hierarchy within events is observed. In this example `was set aside` is the key event, however, phrases like `Sagar joined Akbar`, `granted the title`, `installed at Chittor`, `were restored`, etc. indicate related and sub-events of the key event.

7.6 Location-Actor ambiguity

There are many instances where a location is associated with event verbs which are applicable on actors. For example in Table 4:R-6, the countries `France, Britain, Austria, Russia` are not locations, rather they are actors of type organization.

7.7 Event title generation

While visualizing a timeline instead of showing a complete event sentence, it is more useful to generate and show a short and succinct title for each event. However, generating such a title is challenging.

Events in text are typically described using verbs. One straight-forward approach to generate title of an event could be to use the main action verb and its associated subject(s) and object(s). However, in many cases, events are also described using non-verbal (e.g, nominal) expressions. For instance, consider the sentence – `The Great Depression lasted from 1929 to 1939.` Here the event `The Great Depression` occurs in nominal form.

In other cases, event sentences may contain multiple sub-events (e.g., Table 4:R-5). They can be associated with actors, location, time/date, relations or with other events. So it is important to identify the different kinds of events to come up with a succinct title describing the complete event.

7.8 Evaluation

There are three important aspects on which an automatically generated timeline should be evaluated. The first aspect is precision and recall of events extracted from the text. This aspect mainly does an evaluation of event extraction component of timeline generation algorithm. The second aspect is an evaluation of title generation and extraction of relevant named entities from text. The third aspect is an evaluation of order of events in an automatically generated timeline. It is important to note that these three aspects are interlinked to each other. Hence, it necessitates appropriate evaluation measure(s) for timeline evaluation that will collectively consider the three aspects discussed above.

There is also need of live user studies where students of history participate to evaluate utility of timeline visualization techniques in understanding historical phenomena. We will explore both empirical and user evaluation of timeline generation in the future.

8 Conclusions and Future Work

In this paper, we propose a system for generation of event timeline from history textbooks. We also propose two techniques to visualize a timeline. Message Sequence Chart based visualization enables a student to observe involvement of multiple actors in a historical phenomenon. On the other hand, time-map based visualization enables a student to understand spatio-temporal aspects. We believe that both these visualization techniques will increase a student's interest and curiosity in learning history as a subject. Hence, in addition to a working system, we also identify key computational challenges in creating NLP based applications for history subject. Of course, the system proposed in this paper can be improved across many dimensions. Currently, we are generating a timeline specific to a human actor. In the future, we would like to generate a timeline for a non-human actor, e.g., a timeline of *art or science in the Renaissance*. We also aim to define annotation guidelines for annotation of historical events and release a much larger annotated dataset that can be used for various tasks such as entity/event extraction and segmentation, co-reference resolution of named entities as well as events.

[11] https://en.wikipedia.org/wiki/Mewat

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