What it Boils Down to... The Case for Event Analogies to Combat Complexity in Digital Libraries

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Abstract

Making sense of an increasingly complex world is becoming harder in particular when facing the flood of information available in digital libraries. Hence, actively supporting users in sense making activities is a new challenge that digital libraries have to face. A popular way for humans to succeed at making sense of the world is the usage of analogies: Analogies transfer some high-level meaning from one concept to another which eases the cognitive burden to understand the concept. In brief, they connect a known concept to the unknown. A prime example is to find analogies between current and historic events to make sense of current events, i.e., place them in contexts, assess their impact, and draw conclusions on what may happen next. In this position paper, we outline a system architecture showing what an event analogy system could look like. We utilize a conceptual narrative model and define narrative roles and prototypes as a possible solution for finding event analogies.

Keywords

Analogies, Narratives, Narrative Prototypes

1. Introduction

September 11, 2001 two planes hit the World Trade Center in New York City, resulting in a collapse of the main towers and the death of nearly 3000 people. The aftermath of the 9/11 attacks is still palpable even after nearly 20 years have passed. Usually it does not take events of the size of 9/11 to invoke a need of making sense of what happened. In this context "making sense" means to understand an event s.t. one can build a mental model of it and draw conclusions regarding what happened, why did it happen and what might be happen next (similar to the verdict in [1]).

We often rely on history to find similar instances from the past to understand what happened now and what may still happen based on the historic events. The media coverage of 9/11 for instance often drew a comparison to the attack on Pearl Harbor in 1941 by the Japanese army [2]. Moreover, street interviews shortly after the 9/11 attack also yielded the comparison to the Pearl Harbor attack (see for example [3]), therefore "Pearl Harbor" may be seen as an *analogy* to "9/11". In contrast to literal similarity, an analogy tries to transfer some high-level meaning from a base to a target [4] but does not require common attributes or attribute values. But how would a digital library find and offer good analogies?

Digital libraries (DL) offer a wide range of information regarding events in both, structured formats like knowledge graphs [5] and unstructured formats like news articles or historic documents. Analogies can help users to reduce the complexity introduced by the vast amount of information by connecting events in a way which is stated to be a core part of human cognition [6]. From a users perspective this would not only ease the understanding of "what happened" but it would also provide hints on what could come next (e.g., after the Pearl Harbor attack the USA joined World War II and after 9/11 the war in Afghanistan).

In this position paper we explore possibilities to find event analogies with controlled quality. Most research in the area of analogies and analogical reasoning in computer science has been performed on 4-term analogies (e.g. Paris is to France what Berlin is to Germany) [7], which are a simple case of analogies. Thus we need to define a different path to understand analogies specifically tailored for events in digital libraries. Therefore we first explore theories on analogies from cognitive science along with the state of the art possibilities to compute analogies in Sec. 2. Additionally, we have to account for the heterogeneity of data sources available in real world DLs, i.e. event information may be fragmented in structured and unstructured repositories but both worlds are needed to find an analogy.

We tackle both problems building on a recent conceptual model for *narratives* [8]. Narratives can be used as an encapsulation of a single or multiple events, thus binding them against available data sets (Sec. 2). We define the concepts of *narrative roles* and *narrative prototypes* to account for analogies (Sec. 3.1) and propose a conceptual system architecture for an event analogy system (Sec. 3.2). Finally we give an outlook on what tasks might be a good starting point for future research (Sec. 4).

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2. On Analogies, Events, and Narratives

2.1. Analogy Models

One theory on analogies is the *Structure-Mapping Theory* (SMT) introduced by [9]. SMT describes analogies as a comparison between relational predicates of two concepts compared in the analogy (called *base* and *target*). For instance, the 9/11 to Pearl Harbor analogy can be seen as an analogy, because central underlying relations (surprise attack on a country, national shock, relation to a war following the event) are comparable.

Another model of analogies is the *High-Level Perception Theory* (HLPT) [10] which states, that a spectrum between lower level perception (like detecting that a certain object is a tree) and high-level perception (i.e. complex concepts like war) exist and analogies are defined by a mixture of high-level and low-level perception interweaving. For events this means that e.g. the public opinion on certain events play a role in perception and therefore Pearl Harbor is more likely to be seen as an analogy to 9/11 and not, for instance terror attacks outside of the USA.

Originally, HLPT was described as a competing theory to SMT [10] but it was later shown, that both theories can be seen as somewhat orthogonal [11]. SMT in that notion describes whether a given base and target tuple can be seen as an analogy, i.e. the structure mapping process between both succeeds. HLPT then goes beyond comprehension and may be used to produce analogies by building cognitive representations on the spectrum of perception for a given set of objects or concepts and then find matching representations.

2.2. Computing Analogies

Most research regarding computing analogies has been performed on 4-term analogies, where two base-target tuples are compared regarding a specific (set of) relation(s), e.g. Paris is to France what Berlin is to Germany (in short Paris:France $\sim_a$ Berlin:Germany) in the sense of a *capital_of* relation. Before 2013 most works regarding the computation of analogies were based on logical reasoning, case-based reasoning, and relationship extraction by using *Natural Language Processing* (NLP) techniques (see [7] and section 4.1 in [4] for an overview). Yet, most of these approaches have been only minor successes. In 2013 due to the development of word2vec [12] continuous vector space models for large corpora gained traction. The vector space created by word2vec could be shown to capture certain dominant parts of word semantics, e.g., the vector for "Cuba" may be approximated by [Norway] − [Oslo] + [Havanna] ≈ [Cuba] [13]. In other words, continuous vector space models indeed allow the computation of 4-term analogies up to a certain degree and have therefore been used in various works to capture these analogies since then (e.g. [14, 15]).

However, although the existence of linear relationships as shown in the Cuba example is proven for word2vec [16], they limit the scope to word pair analogies, making them unsuitable to go beyond 4-term analogies. Additionally, some works suggest that the workings of word embeddings in analogical querying highly depends on the corpora and the relations used (see e.g., [17]), limiting the possibilities of simply relying on word2vec even further. Recently, more complex neural models have been used to improve the quality of finding analogies. While some of them use language models to compute 4-term analogies [18] others model a deep learning architecture mimicking the SMT on synthetical data [19]. However, Ushio et al. [18] stated, that the deep models overall did not outperform the word embedding models. The work of Crouse et al. [19] was solely used on synthetical data, therefore no results for real-world applications exist yet.

2.3. Events and Narratives

Events can be seen as incidents between actors in space and time [20]. Considering structured data vs. unstructured data we can differentiate between modeling events in event ontologies with a defined schema and event extraction, which aims to extract events from text. Event extraction tasks often use event schemas in various degrees of complexity [21]. Event schemas are made of a number of event slots or *participants* which have a certain role in the event (e.g. a "football match" event may have two participants in role "participant" and both participants could take the additional role "winner").

In contrast, event ontologies focus on the semantic aspects of events. An example for a event ontology model is the Simple Event Model (SEM) [22], which additionally allows to model sub-events (a football world cup consists of a number of matches) and changes in roles w.r.t. some authority. Indeed, SEM is also practically used for modeling events in knowledge graphs, e.g. in EventKG [5], allowing for a structured representation when retrieving events from a knowledge graph instead of raw text.

To bridge the gap of structured and unstructured sources and to unify and combine events and entities in a meaningful way, a conceptual model for narratives has recently been proposed [8]. Here narratives are cast as directed graph-structures residing in a semantic overlay structure on top of knowledge repositories. Through strongly typed relations events can be structurally combined with entities and subsequently both elements can be bound to a given knowledge repository (e.g. a knowledge graph or a document collection), see [23] for details.

By building a logical overlay above the respective knowledge repositories, narratives are capable of model-

ing event chains without losing provenance information regarding the validity of each relation also in the sense of information fusion over different repositories. In contrast, event schemas typically only model single events and SEM can not model inter-event relationships other than sub-event chains at all. Moreover, narrative structures in cognition have long been shown to be an efficient way of transporting experiences and meaning between humans [24], which makes them suitable as an abstraction for events in the task of finding event analogies.

3. Designing a DL System for Event Analogies

As argued in Sec. 2.1, an analogy does not solely rely on attribute similarity, but on comparable mental structures. Thus, we need an approximation of those structures for events to measure whether two events might be cast as an analogy or not. As mentioned above, analogies can be led back to different theories: While the SMT relies on the similarity in underlying mental structures, the HLPT adds to the notion that analogies are made by connections between perception and cognitive concepts. We argue, that event analogies should rely on both theories up to a certain degree and propose, that event analogies can be determined by two components: *Event Structure Similarity* (ESS) and *Event Perception* (EP).

Event Structure Similarity: SMT needs base and target to share some common relation and also in the case of events humans tend to build analogies between events of similar type [2]. Yet, a strict requirement to be of exactly the same ontological type might be far too restrictive in everyday analogies, especially when using common metaphors. Instead types should adhere to the same *prototype*. Given an event taxonomy, the prototype of some event is the most general superclass for the respective event that does not lose the core characteristics of the event. For instance, the event prototype "confrontation" might refer to both, an armed conflict or a football game. Typically we assume confrontations to be some kind of (peaceful or violent) fight between a number of participants where one party wins, which describes both events in an abstract way, even though war and football do not have other major attributes in common. In other words, a competition between sport teams and a battle between two countries, share the same prototype type of a conflict situation. And while not being similar in their perception, they may still be used as analogies as is sometimes the case e.g., in boulevard media during large football tournaments.[1]

Event Perception: According to HLPT perception and concepts are heavily interwoven. The same event structure may therefore not be enough to capture analogies. We argue, that events can be interpreted from different *viewpoints*. The SEM already allows changes in the roles for participants in an event, but a viewpoint can also alter event types and their connotation (e.g. the accession of Crimea to the Russian Federation is usually interpreted as annexation by western media while Russian sources see it as a peaceful secession). Changes in viewpoints therefore heavily influence the set of candidate analogies for the target and need to be taken into account.

Combining aspects of both, ESS and EP, we can enhance narratives. Narratives as proposed in [8] can depict events and their participants on different levels of granularity and at the same time combine knowledge from various repositories. However, viewpoints are not part of this conceptual model yet. Therefore we will extend the narrative model for the usage as an event analogy model in Sec. 3.1, before we introduce a conceptual system architecture of an event analogy system in Sec. 3.2.

3.1. Narrative Roles and Narrative Prototypes

Determining whether a given base and target can be seen as a fitting analogy is a hard task, even for humans. And as statistical models are likely to only find analogies between events often observed together, we argue that finding event analogies is not successful without providing at least some human-modeled semantic elements.

While the 9/11 $\sim_a$ Pearl Harbor analogy as often referenced example in literature might be easily discovered, the analogy between the UEFA soccer cup finals of 2004 and 1992 may easily be missed: In 1992 Denmark won against Germany while in 2004 Greece beat Portugal despite the latter teams being the clear favorites. Examples for this particular scenario are plenty: just recently, Switzerland won against the current soccer world champion France during the UEFA cup in 2021.

All instances share a common narrative prototype which might be called the "David vs. Goliath"-narrative based on the biblical figures. The weaker party of the confrontation (the *underdog*) won against the far stronger party (the *favorite*) against all odds in an instance of an event of type *confrontation*. We call these patterns *narrative prototypes* and argue, that narratives that can be matched on the same prototype can be seen as analogies. The most simple narrative prototype consists of a single event which allows a direct mapping from event schemas and event ontologies (specifically SEM) to a narrative prototype. The left portion Fig. 1 illustrates this mapping by trying to map the two Euro cup finals from above to the "David vs. Goliath" prototype. Greece and Portugal on the one hand and Germany and Denmark on the other hand are used as substitutions for the participants ?X and ?Y of the special confrontation prototype, where

[1] See [25] for an often cited example of this analogy.

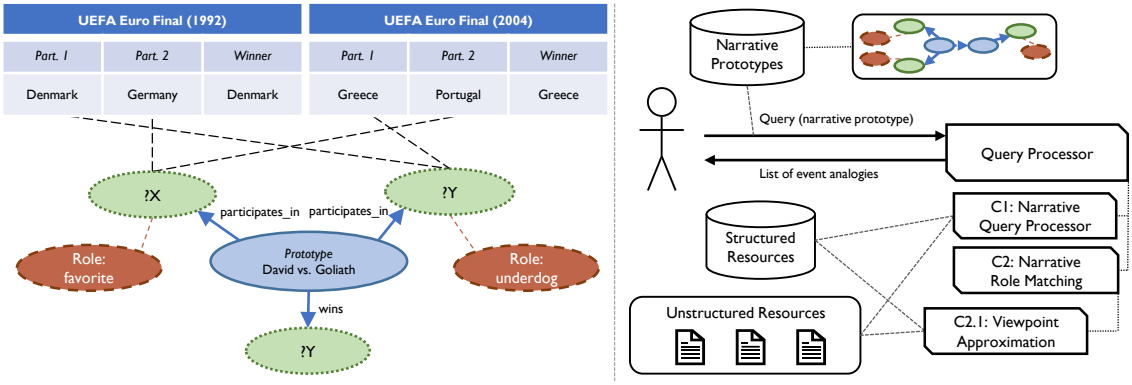

Figure 1: Left portion: event schema mapping to narrative prototype. Right portion: sketch of the system architecture.

the respective winner must be substituted by ?Y.

Regarding event perception we propose *narrative roles* for the modeling of narratives as shown here for underdog and favorite, respectively. Both roles have a semantic meaning and must be checked after the substitutions, i.e. the narrative prototype only fits, if both participants do not violate any role constraints. Role constraints in the case of Fig. 1 mean, that the participant substituted in ?X must be significantly "stronger" than the one substituted in ?Y, where "strength" is defined by the concrete type of event described by the prototypical event "David vs. Goliath" (in Fig. 1 international soccer matches). In this example the prototype calls for narrative roles like underdog and favorite but a role like "emissary" might not be a sensible role, the prototype should therefore restrict the narrative roles that can be used in its context.

3.2. System Architecture

Building on the design in Sec. 3.1, we propose a novel architecture for a event analogy system in the right portion of Fig. 1. Users are enabled to retrieve lists of analogies as results of respective queries. Queries generally contain narrative prototypes taken from a separate repository. Currently this repository is manually curated by domain experts, but it might become possible to automatically derive suitable prototypes in later stages of the system development.

The query processor then needs to perform two tasks: a) find suitable substitutions for the prototypes based on the events available in structured and unstructured formats and b) check whether the substitutions fit their respective narrative roles or not. All narratives fulfilling a) and b) are returned as analogies. To tackle task a), the narrative query processor (C1 in Fig. 1), performs a narrative binding against the data repositories following the basic method of [23]. But in contrast to the narrative bindings in [23], C1 focuses on events in each prototype in the narrative to substitute the participant variables (?X, ?Y, etc.).

Defining such bindings requires the operationalization of prototypes. In particular, algorithms to determine which events fits which prototype must be able to determine whether a superclass of some given event contains the inherent structure typical for the event or not. In other words: a event e belongs to the prototype e^p, if the distance of its ontological concept does not surpass a given threshold. Thus, the system needs a semantically curated view on the underlying ontological structures, i.e. how far could one generalize an event without losing its inherent meaning.

Regarding task b), component C2, the narrative role matching is used. As explained in Sec. 3.1, narrative roles carry a clear semantic meaning (as in the "underdog"). The manifestation of these semantics does not only depend on the prototypes, but also on the concrete type of the event. For instance, the confrontation prototype may define underdog as a *drastically weaker* participant in comparison to the favorite. However, the concrete features to measure the strength depend on the concrete event: For soccer games strength might be measured by current titles or recent successes (like world cup rankings or leaderboard positions) or the monetary net worth of the team. In warlike confrontations the military strength needs to be determined. Of course, defining the relevant features for all event types in all prototypes manually is cumbersome. Therefore means of approximating those features will be needed in future.

Following the HLPT and the EP component of analogy detection, we take different viewpoints into the equation with component C2.1. While net worth and championships are objective measures, narrative roles may also include features which are heavily influenced by different viewpoints. A viewpoint in this regard could be a different event type in a narrative, i.e. an event analogy with more than one event. Take for instance the Crimea

accession, which could be seen either as an annexation or as a peaceful secession. Depending on the viewpoint, the respective event type changes and may lead to different features and thus understanding of the narrative roles. Viewpoints may be approximated by leveraging context information from mostly unstructured sources like news, historic documents or, if available, social media content. This problem needs more refinement regarding how narrative roles are connected to viewpoints and how these viewpoints may be approximated.

4. Outlook

In this position paper we presented a first design for an event analogy system. The next step is the development of algorithmic ideas regarding the open questions, starting with:

- How can event prototypes be defined and how to measure distances between prototypes and events in respective taxonomies?
- How can narrative roles and event participants be matched and substituted?
- What is the exact connection between narrative roles and viewpoints in a narrative prototype?

Finally, a larger set of concrete narrative prototypes needs to be built up before a system prototype can be properly implemented to test the practical usefulness of event analogy systems in digital libraries.

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