Using Multiple Storylines For Presenting Large Information Networks

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Abstract. Storytelling has always been an effective and intuitive method of exchanging information. In today's world of large, open, structured data, storytelling can benefit the ways in which people explore and consume such information. In this work, we investigate this potential. In particular, methods for creating multiple interweaving storylines are explored for tying together possibly disparate veins of exploration in such large networks of information and helping maintain audience interest. This paper presents the algorithms for automatically generating interweaving storylines, followed by examples and discussions for future work.

Keywords: interactive narrative · multiple storylines· big data · DBpedia

1 Introduction

Narrative is one of humankind's earliest forms of exchanging information. People have been telling stories for as long as there have been stories to tell, entertaining each other, sharing the happenings in their lives, passing on knowledge they have learned themselves or learned from others, and swaying each other's opinions. As a communication device, storytelling is an effective and memorable way of giving others information.

The modern web provides unprecedented access to large networks of information. Online encyclopedias like Wikipedia, with over five million articles in English, can be traversed and explored by anyone with a web browser and an Internet connection. These sources of information are comprised of large collections of data that are linked and related to form large networks, and present an opportunity for people to tap into and learn about diverse topics. To explore such large network of information can be enjoyable, but it can also be a time consuming task. One difference between this exploration and reading a book or a website is that the information is highly connected and there is not a clear thread of how the reader should proceed. Web browsers are mostly passive, responding to searches rather than proactively providing information.

The goal of this project is to create a personal guide to help people explore and consume information by leveraging interactive narrative technologies. Narrative and storytelling have always been an intuitive method for humans to share and organize

information. According to Abbot, humans mainly organize their "understanding of time" through narrative [1]. Time is thought of and reasoned over as a narrative, with events linked by their temporal sequence. Similarly, Bruner states that narrative is the main method by which we organize human "experience and our memory of human happenings" [2]. We remember our experiences as stories, linking the individual facts of the events in our lives in a narrative way. Neumann and Nünning also support this point, calling narrative the "fundamental way" that humans organize knowledge [6].

As an initial step, we defined an XML format for encoding information, and developed an automated program for crawling information from DBpedia. In our previous work, an automated storytelling system was developed to present the information in these XML files as a never-ending story [7]. Starting from anywhere in the information network, the system picks its next topic by taking into consideration a combination of factors ranging from topic consistency and novelty, to learned user interests. The system also allows the user to direct the presentation by changing the current topic, or the relative weights the system uses for balancing the contributing factors in its selection of the next topic.

The results from our previous work can be visualized as a single story line navigating through the network of information. In entertainment-orientated narrative forms, e.g. movies, novels, and games, multiple interleaving storylines are often used for introducing a wider range of topics and for making the story more dynamic and more engaging [8]. In this work, we experiment with using this technique for presenting Internet data. Individual storylines are generated based on author-identified topics – what we refer to as anchor points – using the algorithms presented in our previous work [8]. We propose new algorithms for combining and interweaving such sequentially constructed storylines. We present these algorithms in detail, followed by an example of how they can be used for creating a story presentation with multiple and interweaving story lines, and discussions on future work.

2 Related Work

2.1 Presentation over Structured Information Networks

The demand for methods of exploring and presenting information in large networks is currently being met by several types of systems, including recommendation systems, data visualization systems, and narrative agents. These three types of systems carry different strengths and weakness.

Recommendation systems, such as the web recommender *Letizia* or book recommender *LIBRA*, are specialized at learning user preferences and filtering information based on user profiles to suggest potentially relevant information to the user (see [11] for a comprehensive review of recommendation systems.)

A variety of graph-based data visualization techniques have been developed for large networks of linked data, consisting of different node-link visualizations of RDF, OWL, and Web of Linked Data sources [12]. Node-link visualizations give users a wide glimpse at information networks, showing the relationships and interactions between many individual pieces of information.

Typically, neither recommendation systems nor data visualization systems pay attention to the path a user takes through the exploration process, i.e. whether the process is interesting or whether it helps the user to summarize and remember information.

Conversational agents are often specialized at utilizing conversational techniques, such as small talk, dialogue schema, and storytelling to help the user feel more comfortable and organized about the presented information. Information presentation systems have been developed with embodied conversational agents for various purposes, including tour guides, personal assistants, and tutors [4][13][14][15][16][17][18]. Most automated presentation systems require the information to be manually encoded. A few systems have been developed for directly using data from the Internet. Tarau and Figa designed a conversational agent that is capable of answering the user's questions by extracting information from a story database with RDF metadata. It can also make inferences based on context of the conversation [9]. Cruz and Machado created a data visualization system that utilizes storytelling techniques for presenting large scientific data [5]. In our previous work, we have created an automated presentation agent that utilizes storytelling techniques for presenting information from DBPedia [19]. This system will be presented in detail in Section 4.

2.2 Interweaving Storylines

Having multiple interweaving storylines is a common technique in novels and movies for engaging the audience, and also for helping to present complex relationships among the events or characters in the story. Our work is motivated by Tan's theory and analysis on the foreground and background storylines in storytelling. As Tan points out, audience members have a natural urge to satisfy cognitive curiosity [8]. He discussed two types of audience interest, which are generated by the active line of action in a film, and by storylines that are not currently being pursued. The active line of action advances a single storyline, directly capturing the audience's interest and allowing them to follow it. This is called the foreground storyline. Storylines may be suspended before their conclusion, allowing different storylines to come into the foreground. Doing so leaves the audience with questions, stimulating interest about the suspended storyline's conclusion. Storylines suspended this way are said to be in the background. An interweaving consists of multiple storylines beginning, suspending, restarting, and concluding, with each storyline dipping in and out of the foreground. Figure 1, below, shows a short story, with story sequences, made from interweaving two storylines. Blue indicates content from the storyline in the top left, while red indicates content from the storyline in the bottom left. The story describes one storyline at a time, suspending progress on the other storyline until it is resumed later.

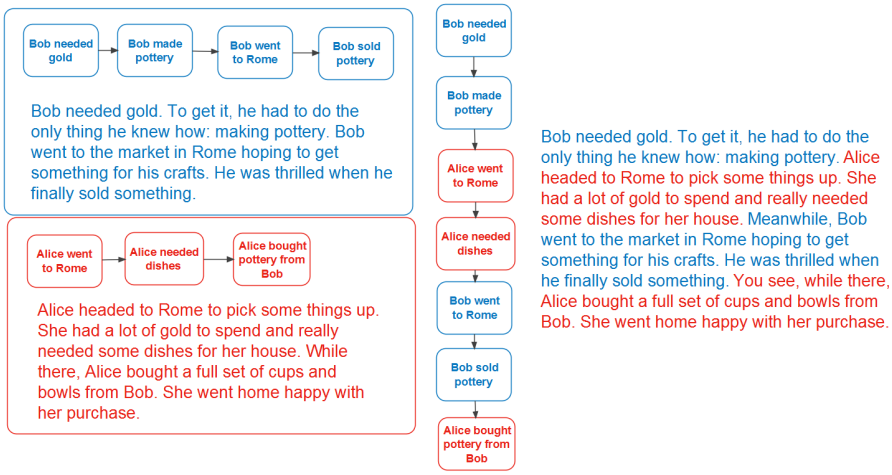

Fig. 1. Short story made from interweaving two individual storylines.

Having multiple storylines can also help with making information more memorable. Between two interwoven storylines, principles from framing and local structure can affect how the information between both storylines is interpreted by the audience. Framing involves discussing one topic, or storyline, using another, more understood topic, or storyline, as a frame of reference. Individual pieces of information from the storyline being discussed, particularly those that relate to the storyline acting as a frame, are consequently made more salient, making them more likely to be remembered and attended to [3]. For example, if a news story about a drug-related crime is presented in the middle of a segment about the "War on Drugs," pieces of information about the crime related to the "War on Drugs" narrative, such as whether anyone was injured, what drug was involved, or whether suspects had any connections with previous drug-related arrestees, may be viewed as important and attended to by the audience.

Similarly, how an interwoven story is structured with regards to how one storyline refers to the other can also have an effect. By creating local structures in the story emphasizing the way in which information is related between two storylines, the interweaving can appear more cohesive and coherent [10]. For example, in the story in Figure 1, the fact that Bob needs gold and that Alice has gold, as well as the fact that Bob makes pottery and that Alice needs dishes, is juxtaposed in the first few sentences. The local structure employed helps reveal that the information in both storylines are related, and that their paired presentation may have a coherent purpose.

3 Example Domain

The example domain for this work is Arctic exploration. Information about this domain was gathered from DBPedia pages, and an information network was generated

using an in-house tool for extracting networks from subsets of DBPedia. The tool uses a modified breadth-first search, filtering out certain uninformative or purely structural edges and nodes for gathering the information. Each page in DBPedia is taken as a node, with named links between pages taken as edges, to form our information network's knowledge graph.

This example domain was generated centered on a specific root node -- the page on Arctic exploration. Knowledge encoded include objects, people, organizations, locations, events, and concepts. The exact subset used consists of 500 nodes, with 1023 edges constructed from 139 unique relationships. Figure 2, below, shows a small excerpt from the knowledge graph. Though only one directed relationship is shown between each pair of connected nodes, a reciprocal relationship in the opposite direction exists for each edge.

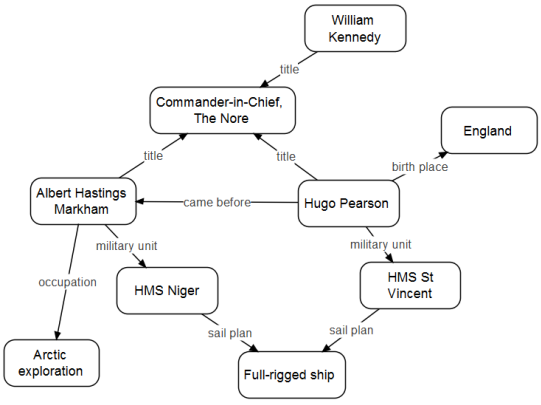

Fig. 2. Node-link diagram of portion of knowledge graph for Arctic Exploration.

4 Single Storyline Generation

In this section, we briefly review our previous work on presenting information from a knowledge graph as a never-ending story [7]. The algorithms in [7] serve as the basis for the work we propose in this paper on generating multiple interweaving storylines.

In [7], a storyline is generated in a greedy fashion by picking the next topic one at a time. When determining the next topic, the narrative agent balances a set of narrative objectives, including introducing novel content, maintaining hierarchical and spatial ordering consistency in its descriptions when applicable, including content closely related to inferred user interests, and any additional objectives specifically defined by the authors (e.g. partial ordering of topics or grouping of topics in the presentation). Each potential next topic is evaluated against all of the objectives, and the weighted sum of all objective scores indicates how optimal the node is as the next topic. Changing the weights of the objectives affects the style of the presentation, such as merging in more novel content vs. providing more details around topics presented before. Typ-

ically, all of the nodes in the knowledge graph are considered as potential next topics, though the designer of the agent can limit this range.

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n = current node in story, m = potential next node in story

Novelty is how new or unexpected a node, m, is relative to the current story.

Novelty(m, n) = w_0* (distance m to n)/max possible distance – w_1*(percentage of unvisited neighbors of m) – w_2* (if m has been visited)

Spatial Ordering Constraint is whether presenting a node, m, now is consistent with the presentation's existing spatial ordering.

Spatial Ordering (m, n) = 1 if relationship between m and n is spatial and pointing in the same ordering direction as previous turns, 0 otherwise.

Hierarchical Ordering Constraint is whether presenting a node, m, now is consistent with the presentation's existing hierarchical ordering.

Hierarchical Ordering (m, n) = 1 if both m and n have the same hierarchical relationship with another node, 0 otherwise.

Score is how appropriate a node, m, would be for the next node in the story, given novelty, spatial ordering, and hierarchical ordering weights w_n, w_s, and w_h, respectively.

Score(m, n) = Novelty(m, n) * w_n + Spatial Ordering(m, n) * w_s + Hierarchical Ordering(m, n) * w_h

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Fig. 3. Overview of major narrative constraints.

A storyline is a sequence of nodes from the knowledge graph. To reveal and emphasize the relationships between the topics, presenting a storyline involves both showing the descriptions of each node and using transition phrases to link nodes together. The narrative agent can apply several techniques for forming transition phrases, such as making analogies between current and previously mentioned topics, explicitly mentioning how the current and next topics relate to each other, and signaling topic transitions. The latter two techniques are most commonly used. The new HINT-AT and TIE-BACK functions we propose in this paper are also forms of transition phrases. When multiple strategies can be applied for forming a transition phrase, the authors of the agent need to supply rules for their priorities. For example, in this work priority is always given to HINT-AT and TIE-BACK transitions.

Figure 4 shows a piece of narrative generated by the presentation agent. Text between brackets consists of transition phrases generated by the system. Other text consists of topic descriptions taken directly from DBPedia by our program. The segment in Figure 4 is composed of ten nodes. In Section 6, we will show another narrative segment with multiple interweaving storyline of similar length, making the difference in presentation styles between our new system and our existing work clear (Fig. 8).

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1. {First, let's talk about Arctic exploration.} Arctic exploration is the physical exploration of the Arctic region of the Earth.

2. {Albert Hastings Markham's occupation was Arctic exploration.} Admiral Sir Albert Hastings Markham, KCB was a British explorer, author, and officer in the Royal Navy.
3. {Albert Hastings Markham's military unit was HMS Niger (1846).} HMS Niger was an 8-gun screw sloop launched on 18 November 1846 from Woolwich Dockyard.
4. {HMS Niger's (1846) sail plan was a full-rigged ship.} A full-rigged ship or fully rigged ship is a sailing vessel with three or more masts, all of them square-rigged.
5. {HMS St Vincent's (1815) Ship sail plan was full-rigged ship.} HMS St Vincent was a 120-gun first rate ship of the line of the Royal Navy, laid down in 1810 at Devonport Dockyard and launched on 11 March 1815 before a crowd that was put at 50,000 spectators.
6. {Hugo Pearson commanded HMS St Vincent (1815).} Admiral Sir Hugo Lewis Pearson KCB was a Royal Navy officer who served as Commander-in-Chief, The Nore.
7. {Hugo Pearson's title was Commander-in-Chief, The Nore.} The Commander-in-Chief, The Nore was an operational commander of the Royal Navy.
8. {William Kennedy (Royal Navy officer) held the rank of Commander-in-Chief, The Nore.} Admiral Sir William Robert Kennedy GCB was a Royal Navy officer who went on to be Commander-in-Chief, The Nore.
9. {William Kennedy's (Royal Navy officer) military branch was the Royal Navy.} The Royal Navy is part of Her Majesty's Naval Service, which also includes the Royal Marines.
10. {The Royal Navy garrison is in London.} London /ˈlʌndən/ is the capital and most populous city of England and the United Kingdom.

Fig. 4. Single storyline generated in Arctic Exploration domain.

5 Generating Multiple Interweaving Storylines

5.1 Anchor Nodes

In our previous work [7], there is no guarantee for any specific topics to be visited during an exploration. However, authors of presentation agents often need better control over the content of the presentation. For this purpose, we introduce the concept of anchor nodes in our system. As with recommendation systems and virtual tour guides, certain pieces of information may be considered important to mention. We call these pieces of information anchor nodes. Each anchor node corresponds to a node in the knowledge graph. They can either be manually defined or automatically generated.

With multiple anchor nodes, the new challenge we face is how to visit them and their related content in an optimal order. Each anchor node can guide the development of a storyline using our existing system [7].

Take the red and blue storylines in Figure 5. As shown in Figure 5 a, presenting the two storylines in a single, sequential way may lead to a confusing, disjoint presentation when the end of one storyline and the beginning of the next are too far away from each other. In this case, the storylines could, instead, by interwoven, as shown in Figure 5 b. In the next section, we present our algorithm for interweaving two storylines,

including how to identify the optimal switch point between them and how to relate the contents from the first storyline to the second storyline and vice versa.

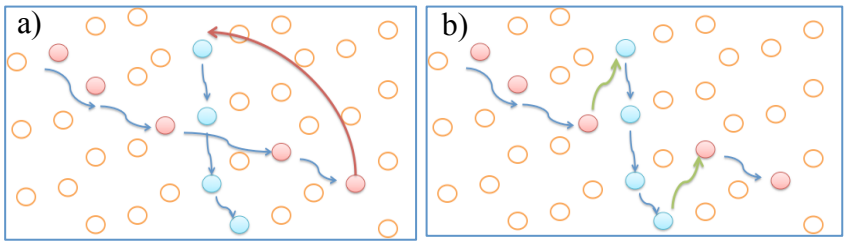

Fig. 5. Interweaving two sequential storylines.

5.2 Interweaving Two Storylines

Currently, we limit interweaving to two storylines with one switch point. Thus, an interweaving consists of one storyline beginning first, progressing to a certain point, switching to the background to allow a second storyline to begin in the foreground, and switching back to the foreground once the second storyline has completed. We call the storyline that begins first the primary storyline and the storyline that begins second the secondary storyline. Algorithm 1 denotes the process for interweaving two storylines.

Determining Interweaving. Before Algorithm 1 is run, the first step is to determine whether adjacent storylines should be separated and interwoven. To accomplish this, the system takes into account how disjoint the transition from one to the other is using the relatedness between nodes. In our work, node distance is used as the main metric for relatedness between nodes, though alternative metrics for relatedness (e.g. semantic relatedness between node descriptions, structural relatedness between stories) can be used instead. If the relatedness of the last node of the first storyline to the first node of the second storyline is below some tunable threshold, the transition is considered disjoint and the two storylines will be considered for interweaving.

Choosing Switch Point. An interweaving of storylines is the creation of local structure. As each storyline leaves the foreground, the set of nodes and information that it has presented to the user gives the next storyline entering the foreground a base to predicate its presentation of information. We call the pair of nodes at which two storylines switch from foreground to background a switch point.

Audience members express a natural yearning to resolve cognitive curiosity. As a storyline is relegated to the background, the interest it garners from the audience is based on what questions are left unanswered by the storyline [8]. When deciding where the switch point should be in the primary storyline, we want to choose the point in the primary storyline where the most curiosity can be aroused in the audience. While it is almost impossible to obtain an accurate model for what will raise the audience's curiosity, in this work, we estimate the audience's curiosity level by how many unanswered questions the presentation agent can raise when it suspends the primary

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1 Algorithm 1. FUNCTION INTERWEAVE(P, Q, t)
2   P                  // primary storyline, a list of nodes
3   Q                  // secondary storyline, a list of nodes
4   t                  // threshold relatedness value
5   if relatedness(P[length], Q[length]) < t then
6     j = index j of P where MAX(# of edges from each P[n],
7             n <= j to each P[k], k > j) // switch point
8     P1 = {P[0] through P[j]}    //1st half of primary
9     P2 = {P[j+1] through P.end} //2nd half of primary
10    for each node q in Q
11      if q is neighbors with any node p in P1 then
12        TIE-BACK(q, p)
13      end if
14    end for
15    for each node p in P1
16      if p is neighbors with any node w in P2 then
17        HINT-AT(p, w)
18      end if
19    end for
20    return {P1 + Q + P2}
21  end if
22  else
23    return {P + Q}
24  end else
25 end function

TIE-BACK(q, p) -- relate information in node q from
  secondary storyline back to information in node p from
  primary storyline.
HINT-AT(p, w) —- allude to undisclosed information for
  node p from first half of primary storyline based on
  relationship to node w from second half of primary
  storyline.
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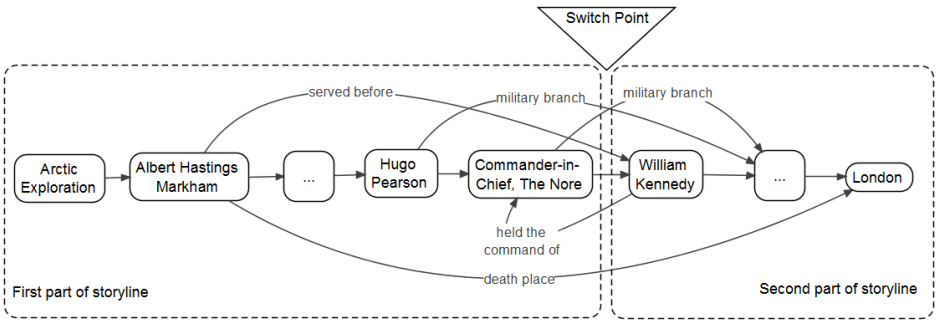
storyline. Computationally, the node *n* in the primary storyline for which there are the most connections from the set of nodes prior to, and including, *n* to the set of node after *n* is chosen as the switch point. Doing so allows the automated storyteller to pose unanswered questions whose resolution will come when the primary storyline resumes. The HINT-AT function, used at line 19 in the algorithm below, takes a node, *p*, from before the switch point in the primary storyline and a node, *w*, from after the switch point in the primary storyline and states the relationship from *p* to *w* without mentioning *w*. An example of a switch point and HINT-AT can be seen in Figure 8,

turn 8, with resolution on turn 18. Figure 6, below, shows the switch point in Figure 8 in context of the primary storyline's structure and the HINT-AT relationships used. Note that the text in Figure 6 is the result of several calls to the HINT-AT function; one for each node-relationship pair referenced.

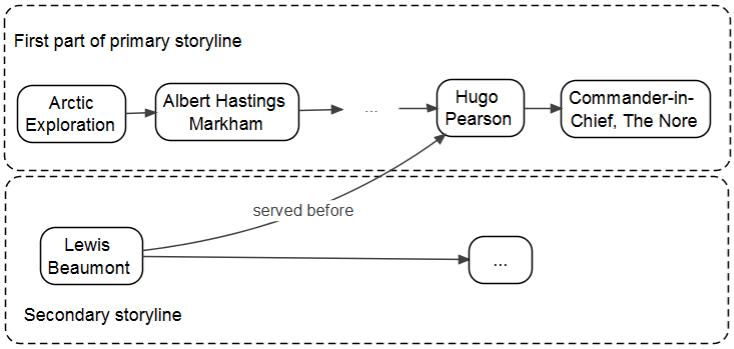


{We'll hear more about who Albert Hastings Markham served before, Albert Hastings Markham's death place, Hugo Pearson military branch, who held the command of Commander-in-Chief, The Nore, and the military branch of the Commander-in-Chief, The Nore, soon.}

Fig. 6. Switch point and HINT-AT relationships (top) with corresponding story text (bottom).

Relating Information Between Storylines. To take advantage of the effects of framing and local structure, information between the two interwoven storylines must be connected somehow. This is accomplished by leveraging direct relationships between the two storylines.

When the secondary storyline enters, the set of nodes and node transitions used in the primary storyline before switching is used as a reference set. When a node in the secondary storyline is presented, if it is directly related to a node in the reference set, the user is reminded of the reference node and their relationship is mentioned. The TIE-BACK function, used at line 14 in the algorithm below, takes a node from the secondary storyline, *q*, and a node from before the switch point in the primary storyline, *p*, and reminds the audience of *p* before stating how *q* and *p* are related. An example of TIE-BACK can be seen in Figure 8, turn 8. Figure 7, below, shows the TIE-BACK in Figure 8 in context of the primary and secondary storylines as well as the relationship used. Note that the text in Figure 7 corresponds to a single call to the TIE-BACK function.



{And do you remember Hugo Pearson? Well, Lewis Beaumont served before Hugo Pearson.}

Fig. 7. Adjacent storylines and TIE-BACK relationships (top) with corresponding story text (bottom)

6 Example Interwoven Story

In this section, we present an example of using interwoven storylines. The following interwoven story was generated with two anchor nodes; "Arctic exploration" and "Lewis Beaumont." We first generated two storylines with 10 nodes each following each anchor node. The two storylines were then interwoven. Similar to Figure 4, text between brackets is generated by the system and text not between brackets is taken directly from DBPedia. After each step, the interweaving methods used in the step are given. For brevity, steps are omitted between steps of interest. Omitted steps are marked by ellipses.

1. {First, let's talk about Arctic exploration.} Arctic exploration is the physical exploration of the Arctic region of the Earth.

   # First storyline begins with anchor node Arctic exploration.
2. {Albert Hastings Markham's occupation was Arctic exploration.} Admiral Sir Albert Hastings Markham, KCB was a British explorer, author, and officer in the Royal Navy.

   …
6. {Hugo Pearson commanded HMS St Vincent (1815).} Admiral Sir Hugo Lewis Pearson KCB was a Royal Navy officer who served as Commander-in-Chief, The Nore.
7. {Hugo Pearson held the rank of Commander-in-Chief, The Nore. The Commander-in-Chief, The Nore was an operational commander of the Royal Navy. {We'll hear more about who Albert Hastings Markham served before, Albert Hastings Markham's death place, Hugo

Pearson military branch, who held the command of Commander-in-Chief, The Nore, and the military branch of the Commander-in-Chief, The Nore, soon.}

 # Primary storyline suspends at switchpoint node Commander-in-Chief, The Nore.

 # HINT-AT information from nodes Albert Hastings Markham and Commander-in-Chief, The Nore, which may be revealed when primary storyline resumes.

8. {But now, let's talk about something else. Let's talk about Lewis Beaumont.} Admiral Sir Lewis Anthony Beaumont KCB KCMG was a Royal Navy officer who went on to be Commander-in-Chief, Plymouth. {And do you remember Hugo Pearson? Well, Lewis Beaumont served before Hugo Pearson.}

 # Second storyline begins with anchor node Lewis Beaumont.

 # TIE-BACK information from second storyline node Lewis Beaumont to first storyline node Hugo Pearson.

…

17. {Midnight Sun (graphic novel) is from the United States.} The United States of America and with over 320 million people, the country is the world's third or fourth-largest by total area and the third most populous. {But that's all we're going to discuss about that.}

 # Secondary storyline ends at node United States.

18. {When we left off our other topic, we were talking about Commander-in-Chief, The Nore. William Kennedy (Royal Navy officer) held the rank of Commander-in-Chief, The Nore.} Admiral Sir William Robert Kennedy GCB was a Royal Navy officer who went on to be Commander-in-Chief, The Nore. I mentioned Albert Hastings Markham before. {As it turns out, William Kennedy (Royal Navy officer) served after Albert Hastings Markham.}

 # Primary storyline resumes at node Willaim Kennedy.

 # HINT-AT information from first part of primary storyline about node Albert Hastings Markham revealed as relationship with node William Kennedy.

…

Fig. 8. Example interwoven storyline from Arctic exploration domain.

The two anchor nodes, Arctic exploration and Lewis Beaumont, are discussed on step 1 and step 8, respectively. The first switch point occurs between steps 7 and 8. When the primary storyline is relegated to the background, a preview is given of what pieces of information relating to the nodes already discussed could be revealed when the primary story resumes later. The secondary storyline begins on step 8. On step 8, an example can also be seen of a relationship being drawn between information in the second storyline, Lewis Beaumont, and information in the first storyline, Hugo Pearson. The second switch point occurs between steps 17 and 18, when the secondary storyline ends and the primary storyline resumes. When the primary storyline resumes, the audience is reminded of where the storyline left off. At step 18, we can also see an example of the resolution of a question raised at step 7 about information from the primary storyline before it was suspended, Albert Hastings Markham.

7 Conclusion and Future Work

In this paper, we describe a method of generating multiple, interweaving storylines from structured networks of information, building off of previous work generating stories and presenting information from information networks. We bring this method to an information network consisting of a small subset of DBPedia, an online open data source, and give an example of an interwoven story from the network.

To take this work further, and to explore the effectiveness of multiple interweaving storylines, evaluations are planned on recall, audience enjoyment/preference, and perceived coherence and cohesiveness of the information presented.

In addition to performing formal evaluations, there are several directions we would like to further extend this algorithm. Firstly, we want to investigate automatically generating the anchor nodes. In the current system, and for the examples given, anchor nodes were manually defined. For a knowledge graph with several thousands of nodes, it may not be easy for the human author to pick all the anchor nodes by hand. We plan to experiment with automatically sampling the knowledge graph and generate the anchor nodes. Secondly, we also want to automatically set the sequence the anchor nodes should be visited. With a large amount of anchor nodes, e.g. a dozen or hundreds of nodes, the human authors will not be able to order them anymore. Finally, we want to develop an intelligent system for deciding how much content the presentation agent wants to present about each anchor point. Currently, this number is fixed or designed by the authors by hand. In the future, we hope to automatically pick the length of the individual storylines based on the nature of the data, prior presentation and interactions with the user, and other anchor points the agent needs to consider.

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