A Semantic Foundation for Mixed-Initiative Computational Storytelling

Ben Kybartas(✉) and Rafael Bidarra

Department of Intelligent Systems, Delft University of Technology,
Delft, Netherlands
{B.A.Kybartas,R.Bidarra}@tudelft.nl

Abstract. In mixed-initiative computational storytelling, stories are authored using a given vocabulary that must be understood by both author and computer. In practice, this vocabulary is manually authored ad-hoc, and prone to errors and consistency problems. What is missing is a generic, rich semantic vocabulary that is reusable in different applications and effectively supportive of advanced narrative reasoning and generation. We propose the integration of lexical semantics and commonsense knowledge and we present GluNet, a flexible, open-source, and generic knowledge-base that seamlessly integrates a variety of lexical databases and facilitates commonsense reasoning. Advantages of this approach are illustrated by means of two prototype applications, which make extensive use of the GluNet vocabulary to reason about and manipulate a coauthored narrative. GluNet aims to promote interoperability of narrative generation systems and sharing corpus data between fields of computational narrative.

Keywords: Computational storytelling · Natural language · Semantics

1 Introduction

Mixed-initiative computational storytelling, in which the author and computer create a narrative by collaboratively building a story, requires a rich and detailed representation of narrative. This is often done by creating a model of narrative, and then providing the author a 'vocabulary', a set of building blocks that can be used to tell pieces of a story and of which the semantics are known to the computer. The 'words' in the vocabulary may take the form of text, images, or even actions, depending upon the application. This vocabulary is often built manually, which, in addition to being time consuming and costly, is also prone to human error and inconsistency and is typically only valid within each specific domain.

We propose the development of a rich, reusable semantic vocabulary in order to provide a solid foundation for computational storytelling applications. Since a mixed-initiative application requires the computer to *reason* about, and *create* pieces of a story, this vocabulary should provide the semantics for both

H. Schoenau-Fog et al. (Eds.): ICIDS 2015, LNCS 9445, pp. 162–169, 2015.
DOI: 10.1007/978-3-319-27036-4_15

the structure and use of each word, as well as more general commonsense knowledge that enables advanced reasoning about the relations between words in the vocabulary.

In this paper, we propose a flexible and generic knowledge-base, GluNet, that seamlessly integrates a variety of lexical databases, facilitates commonsense knowledge consistency and is reusable in multiple domains. In addition, we show how using this rich vocabulary supports the kind of reasoning that is required both to analyze and to manipulate narratives.

To illustrate GluNet's potential as a sound semantic foundation for computational storytelling applications, we present two mixed-initiative prototype applications which make extensive use of GluNet to understand and manipulate narratives alongside one or more human authors.

Lastly, we discuss further directions for the development of semantic vocabularies, as well as the role vocabularies play in approaching open problems in computational storytelling, such as interoperability and the development of a shared narrative representation [10].

2 Related Work

We conducted a review of existing uses of lexical and commonsense resources in narrative or games for best determining which resources are suitable to lay this foundation. Story annotation tools [4,6] often annotate text with a vocabulary derived from WordNet, a lexical database of words [5], and VerbNet, a lexical database of verb semantics and syntax [9].

Alternate forms of annotation have also sought to classify text according to its frame [3], by using FrameNet, a lexical database of frame semantics [1]. Frame semantics has been proposed as a method for narrative generation [13], and FrameNet has further been proposed to help create better natural language processing of questions in story-based games [8]. FrameNet's frame semantics is also a good foundation for the description of events, in relation to structure and semantic roles.

It is also crucial for computational storytelling applications to have a significant amount of commonsense world knowledge to properly understand a narrative from the perspective of a human reader [15], as well as to drive generation or creativity-based applications. ConceptNet [11] is a popular commonsense knowledge-base which has been used in a variety of applications relating both to narratives and to games. Rodriguez et al. [16] created a procedural tool for generating game ideas that subverts ConceptNet's commonsense relations to create unusual and inspiring scenarios. Nelson and Mateas [14] explored the use of both ConceptNet and WordNet to generate complete, thirty-second games where the vocabulary helped them to define game rules.

Previous efforts to unify lexical resources exist, largely intended for use within natural language processing applications. Shi and Mihalcea [17] explored the use of integrated resources for annotation, combining FrameNet, VerbNet and WordNet, which enabled them to exploit the data of each resource to extend

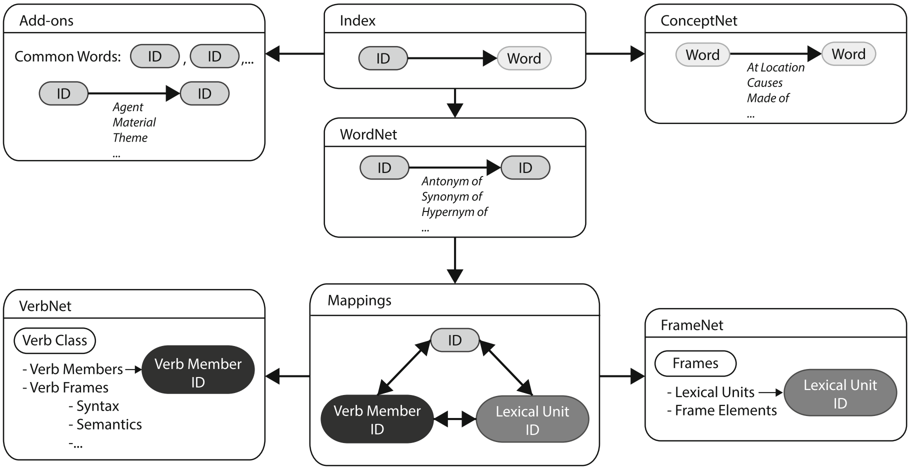


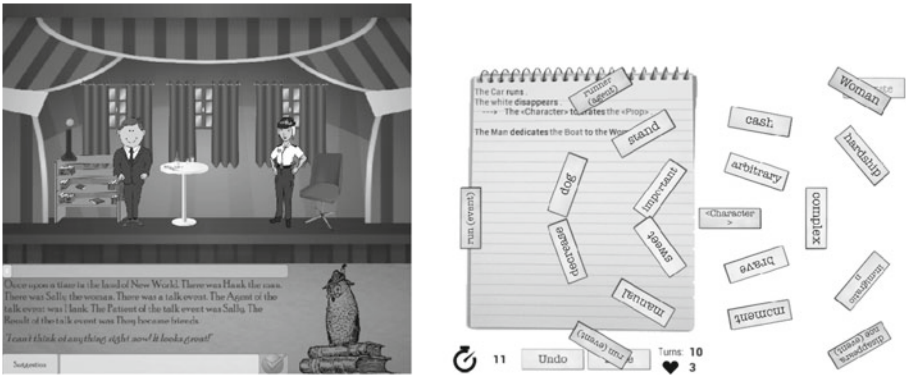
Fig. 1. The abstract structure of GLUNET showing the different components of the knowledge-base, the representation of knowledge in each component, and the way mappings are currently integrated.

the coverage of the other resources. Larger scale integration projects are typically intended for natural language processing, such as UBY [7] which integrates the aformentioned lexical resources along with crowdsourced resources, such as Wikipedia. We differ from the above research in that we integrate commonsense knowledge to derive essential semantic relations that are needed to generate meaningful and coherent content in mixed-initiative applications.

3 The GluNet Knowledge-Base

GLUNET is an SQLite database which provides a vocabulary of words as well as their syntax and semantics. It provides commonsense semantic relations between words, lexical information surrounding single words, the syntactic and semantic meanings of verbs, as well as the frame elements to which the words belong. This was achieved by using the list of words in WORDNET as a primary index, the remaining resources being integrated by either assigning the semantics to a single word, or as a semantic relation between two words. Integration was used to assign the semantics of each resource to a single word, to strengthen the existing resources [17] and to further allow for the creation of new semantic relations [14]. See Fig. 1 for a detailed structure of GLUNET.

The mapping was created using the WORDNET, VERBNET and FRAMENET mappings from the work by Shi and Mihalcea [17] and the similar mappings provided by the VERBNET project. This gives us an incomplete, but extensive, mapping between the three databases. The CONCEPTNET to WORDNET mapping is done at the word level, but lacks the sense key disambiguation of the other mappings which may lead to some inconsistent results when word semantics differ. Future work aims to find methods of bridging these gaps in the mapping, for example by using crowd-sourcing.



(a) SMART STORYBOOK. (b) IMPROV GAME

Fig. 2. Screenshots of each prototype. Figure 2a shows a sample story built in SMART STORYBOOK. Figure 2b shows the noun selection menu in IMPROV GAME.

The main feature of GLUNET is the ability to obtain a significant amount of semantic information for single words. Moreover, we are interested in the advantages of using GLUNET as a semantic foundation for mixed-initiative storytelling applications. To illustrate this, we developed two prototype applications, each requiring some form of narrative understanding and limited generation using GLUNET. The first application is a story-building tool primarily aimed at children, which uses GLUNET to reason and make suggestions about the story being built. The second application is a casual storytelling game that uses GLUNET for text and content generation. Screenshots of both prototypes may be seen in Fig. 2.

4 Smart Storybook

The first application, nicknamed SMART STORYBOOK, is a storytelling prototype designed specifically to allow children experience storytelling in a creative and exploratory way. From the perspective of validating GLUNET, the goal of the application was to be able to reason about narratives as they are dynamically being created. The application is inspired in part by the MY STORYMAKER application [2], in the sense that stories are built by having the child visually create a scene for the story, with the computer providing suggestions on story improvements using a question/answer system. Using the GLUNET vocabulary, however, gives us access to a significant set of WORDNET nouns for characters and props, as well as the semantic information needed to generate questions regarding the story.

A story in SMART STORYBOOK is defined as a linear sequence of scenes. Each scene is manually constructed by the author, by placing three kinds of entities, *characters*, *props* and *decor*, into the scene window. The WORDNET nouns are proposed candidate entities. We selected images for a large subset of WORDNET nouns from https://openclipart.org/.

The analysis and reasoning is largely performed from the event level. To add an event, the author enters the verb of the desired event in the top right box of the interface. The verbs available are the list of verbs available in VerbNet, and the application further checks if there exists a VerbNet-FrameNet mapping for the particular verb. The application then retrieves the verb's thematic roles, leading to an understanding of the roles which need to be filled to complete the event. This generates questions such as 'What is the agent of the fight event?'. If the FrameNet mapping is available, the application will then load the frame elements of the applicable frame. The frame elements allow the application to create further suggestions such as 'What was the style of the dance event?'. All these suggestions may be replied to by the author using the text box at the bottom of the interface. When answered, the response is stored in the event and a new line of text is added to the story. We further experimented with having certain questions, such as those relating to temporality (e.g. frequency and duration), be automatically applied to their corresponding events in the narrative.

Future development on this prototype aims to explore the possibilities of creating an educational tool to teach storytelling. The system currently introduces the author to event/frame-based reasoning and temporality, albeit to a very limited degree. Allowing the application to reason about entities, and even make creative suggestions based on commonsense knowledge, remain interesting avenues for future work.

5 Improv Game

Improv Game is a prototype of a casual improvisational multi-player storytelling game, where players take turns in building segments of a story. Players are first asked to list several characters and props to serve as the starting entities of the story, all taken from the GluNet vocabulary. Once all the entities have been chosen, the game procedurally generates two lines of text, a *starting line* and a *target line*. The current player's goal is to construct the story which connects the starting line to the target line within a set time. Once the player has finished their story, it is the next player's turn and the game generates a new target line. The previous target line now becomes the new starting line, and the new player has to link this starting line to the new target line. The game continues in this fashion until a set number of turns has passed, or when the players run out of time.

Both the procedural generation of lines, and the means by which players construct the story, strongly build upon the semantics provided by GluNet. The procedural generation, in particular, makes heavy use of the WordNet verb frames, as well as the ConceptNet database. First, the application selects the verbs from the most recent sentences in the story. The knowledge-base is then queried to find potential next events from these verbs, by obtaining the *causes*, *has first* or *last subevent* and *has prerequisite* relations to logical next events for the story. If no relations exist from any of the verbs, the application then checks the characters and props in the story, and instead picks a verb based on the character's *capable of* relation. Once the verb has been selected, each piece of the verb frame is filled with a randomly selected character or prop. The players follow the same pattern for creating lines of the story, selecting a verb, followed by a sentence frame and then filling in each piece of the sentence frame using a set of possible values.

The prototype uses the rich semantics of the knowledge-base to link the high-level commonsense reasoning step with the syntactic construction of the sentence. As with Smart Storybook, there is no world model nor consistency check, making it easy for players to 'cheat' or create nonsensical stories. Given the playful and experimental nature of both prototypes, this is not a concern. However, future work aims to examine how the GluNet vocabulary could be used to support a world model, such that some level of story consistency is assured.

6 Discussion

Two areas of importance are: (i) the extensibility of GluNet and (ii) the contribution of a rich semantic foundation towards encouraging interoperability.

Extensibility has been identified by previous integration research as an essential feature, given the growth and changing nature of language and knowledge [7]. We approached this by designing GluNet with a common word index, and by using only open-source or freely available resources to allow for modification and community use. The common word index allows new semantics to be mapped to words in the database. Additionally, future work on GluNet aims to improve and extend the existing mappings to create better coverage.

GluNet was also designed as a first step in the development of a richer representation of story to promote interoperability. With a solid foundation, different applications can share semantics, which is important in interoperability projects where a number of systems generate unique content that must be merged into a final product. One such example is the Slant [12] project, which generates narratives by having a variety of systems create different components of the narrative (plot, discourse, etc.). Without semantics, each system is largely confined to working in isolation, limiting their ability to collaborate, since their foundation knowledge is typically different, and at worst conflicting.

7 Conclusion

The more complex and detailed a mixed-initiative storytelling application needs to be, the more it requires a sound foundation, that will guarantee its generality, expressive power and consistency. For this, a rich vocabulary is needed, integrating lexical semantics and commonsense world knowledge, supporting the kind of advanced reasoning done by computational storytelling applications. We presented a flexible and generic open-source knowledge-base, GluNet, that provides such a semantically rich vocabulary. It integrates several lexical databases and facilitates commonsense knowledge consistency, establishing various mappings and semantic relations among them, in order to support reasoning over a variety of story elements, from different perspectives. The potential of this approach and its ease of integration with computational storytelling applications was demonstrated by means of two case studies, each involving a different mixed-initiative prototype. Both applications profited in different ways from the rich semantics provided by GluNet, which was expressive enough to reason about stories, and even generate narrative content for them.

Among the advantages of a semantically rich knowledge-base like GluNet to the computational storytelling community, we can point out both promoting interoperability of narrative generation systems and the sharing of corpus data between different fields of computational narrative. We expect that further development of better representations of narrative based on rich semantics will open up whole new possibilities for computational storytelling; the semantics-based foundation presented in this paper takes a first step towards this goal[1].

Acknowledgements. This research has been supported by the Netherlands Organisation for Scientific Research, under project no. 314-99-104.

References

1. Baker, C.F., Fillmore, C.J., Lowe, J.B.: The berkeley framenet project. In: COLING-ACL 1998: Proceedings of the Conference, Montréal, Canada, pp. 86–90 (1998)
2. Carnegie Mellon University Entertainment Technology Center: my StoryMaker (2007)
3. Das, D., Schneider, N., Chen, D., Smith, N.A.: Probabilistic frame-semantic parsing. In: Human Language Technologies: The 2010 Annual Conference of the North American Chapter of the Association for Computational Linguistics, HLT 2010, pp. 948–956. Association for Computational Linguistics, Stroudsburg (2010). http://dl.acm.org/citation.cfm?id=1857999.1858136
4. Elson, D.K.: Dramabank: annotating agency in narrative discourse. In: Calzolari, N., Choukri, K., Declerck, T., Doğan, M.U., Maegaard, B., Mariani, J., Moreno, A., Odijk, J., Piperidis, S. (eds.) Proceedings of the Eight International Conference on Language Resources and Evaluation. European Language Resources Association (ELRA), Istanbul, May 2012
5. Fellbaum, C. (ed.): WordNet: An Electronic Lexical Database. MIT Press, Cambridge (1998)
6. Finlayson, M.A.: The story workbench: an extensible semi-automatic text annotation tool. In: Intelligent Narrative Technologies IV Workshop, Stanford, California, USA, October 2011. http://aaai.org/ocs/index.php/AIIDE/AIIDE11WS/paper/view/4091
7. Gurevych, I., Eckle-Kohler, J., Hartmann, S., Matuschek, M., Meyer, C.M., Wirth, C.: UBY - a large-scale unified lexical-semantic resource based on LMF. In: Proceedings of the 13th Conference of the European Chapter of the Association for Computational Linguistics (EACL 2012), pp. 580–590, April 2012

[1] GluNet is available for download at https://graphics.tudelft.nl/glunet/.

8. Joseph, E.: Bot Colony. North Side Inc., Montreal (2014). https://www.botcolony.com/doc/BotColony_paper.pdf
9. Kipper, K., Korhonen, A., Ryant, N., Palmer, M.: A large-scale classification of english verbs. Lang. Resour. Eval. **42**(1), 21–40 (2008). http://dx.doi.org/10.1007/s10579-007-9048-2
10. Koenitz, H.: Five theses for interactive digital narrative. In: Mitchell, A., Fernández-Vara, C., Thue, D. (eds.) ICIDS 2014. LNCS, vol. 8832, pp. 134–139. Springer, Heidelberg (2014). http://dx.doi.org/10.1007/978-3-319-12337-0_13
11. Liu, H., Singh, P.: ConceptNet - a practical commonsense reasoning tool-kit. BT Technol. J. **22**(4), 211–226 (2004)
12. Montfort, N., Pérez, R.P., Harrell, D.F., Campana, A.: Slant: a blackboard system to generate plot, figuration, and narrative discourse aspects of stories. In: Maher, M.L., Veale, T., Saunders, R., Bown, O. (eds.) Proceedings of the Fourth International Conference on Computational Creativity, Sydney, Australia, pp. 168–175, June 2013. http://www.computationalcreativity.net/iccc2013/download/iccc2013-montfort-et-al.pdf
13. Murray, J.H.: Hamlet on the Holodeck: The Future of Narrative in Cyberspace. The Free Press, New York (1997)
14. Nelson, M.J., Mateas, M.: Towards automated game design. In: Basili, R., Pazienza, M.T. (eds.) AI*IA 2007. LNCS (LNAI), vol. 4733, pp. 626–637. Springer, Heidelberg (2007). http://dx.doi.org/10.1007/978-3-540-74782-6_54
15. Rodosthenous, C.T., Michael, L.: Gathering background knowledge for story understanding through crowdsourcing. In: Finlayson, M.A., Meister, J.C., Bruneau, E.G. (eds.) 2014 Workshop on Computational Models of Narrative, vol. 41, pp. 154–163. OpenAccess Series in Informatics (OASIcs) Schloss Dagstuhl-Leibniz-Zentrum für Informatik, Dagstuhl, Germany (2014). http://drops.dagstuhl.de/opus/volltexte/2014/4653
16. Rodriguez, M.T.L., Colton, S., Hepworth, R., Cook, M., Guckelsberger, C.: Towards the automatic generation of fictional ideas for games. In: AAAI Workshop on Experimental AI in Games (2014)
17. Shi, L., Mihalcea, R.F.: Putting pieces together: combining framenet, verbnet and wordnet for robust semantic parsing. In: Gelbukh, A. (ed.) CICLing 2005. LNCS, vol. 3406, pp. 100–111. Springer, Heidelberg (2005). http://dx.doi.org/10.1007/978-3-540-30586-6_9