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Research article

Stories as mental representations of an agent's subjective world: A structural overview

Taisuke Akimoto

Kyushu Institute of Technology, 680-4 Kawazu, Iizuka, Fukuoka 820-8502, Japan

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ABSTRACT

Narrative is a universal form of human information and communication. The generative cognition of narrative will be a core element of a human-like and human-friendly autonomous agent. In the field of artificial intelligence (AI), the knowledge aspect of narrative, including script knowledge and episodic memory, has been studied from a functional perspective. However, this knowledge aspect is rooted in the close relationship between a narrative and how the human mind organizes subjective experiences into a mental representation. We use the term "story" to refer to the uniform mental representation of a piece of a subjective world containing individual meaning and a rich temporal extent. For example, stories include the following types of mental object: an episodic memory, an autobiographical memory, the contextual structure of a current situation, a prospective memory, a planned or imagined future, and a fictional or virtual story. Although narrative cognition is a very complex problem for AI, a cognitive mechanism for dynamically generating mental stories through interacting with external environments is necessary for the ultimate autonomous agent. Considering this long-term goal, in this paper, we provide a structural overview of a subjective world formed by stories as experiences of an agent. In particular, the following structural aspects of mental stories are described: a story-based context of a current situation, association of past, future, and fictional stories, association of others' mental stories, and the distinction between factual and fictitious stories.

Introduction

The generative cognition of narrative will be a core element of a human-like and human-friendly autonomous agent. From the early years of artificial intelligence (AI), the cognitive mechanism of narrative and memory has been researched by Schank and his colleagues (Schank & Abelson, 1977; Schank, 1982). Mateas and Sengers (2003) provided interdisciplinary perspectives on the relationship between narrative and intelligence. In cognitive architecture studies, a narrative or story is studied in terms of episodic and procedural memories (Anderson, 2015; León, 2016a; León, 2016b; Szilas, 2015). On the other hand, from psychological and philosophical perspectives, a narrative is treated as a human method of making sense of the world, including self, identity, personality, others, experience, and time (Bruner, 1990; McAdams, 1993; Ricoeur, 1983-1985).

In this study, we assume that a "story" can be used as a uniform mental representation that forms a piece of the subjectively constructed world inside an agent's mind. This subjective world contains individual meaning and a rich temporal extent, based on the linguistic or narrative-based composition of the information. In this study, the term "story" is used as the unifying concept involving an episodic memory, an autobiographical memory, the contextual structure of a current situation, a prospective memory, a planned or imagined future, and a fictional or virtual story. The cognitive mechanism for dynamically constructing mental stories will be a foundation for the intelligence of an autonomous agent. Considering this long-term goal, in this paper, we provide a structural overview of a subjective world formed by stories as experiences of an agent.

Background: Narrative as memory and knowledge

In the AI field, narrative is researched mainly in terms of creativity, natural language understanding or analysis, and knowledge representation. As background information for this study, this section overviews previous AI studies relevant to narrative's knowledge aspect.

From the early AI years, the relationship between intelligence and a narrative or story has been explored by Schank and his colleagues. They proposed several AI theories of narrative-based knowledge representation models, including script theory and a dynamic memory framework (Schank & Abelson, 1977; Schank, 1982). Script (Schank & Abelson, 1977) is a well-known knowledge representation corresponding to the pattern of the normal flow of events in a specific cultural situation, e.g.,

E-mail address: akimoto@ai.kyutech.ac.jp.

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"eating in a restaurant". They subsequently expanded the script theory to a dynamic memory framework (Schank, 1982) for the dynamic organization of episodic stories.

A key concept in this framework is the memory organization packet (MOP). A MOP is a type of schematic representation of a high-level structure that associates analogous stories. Based on this framework, Schank discussed the cognitive mechanism of the flexible remembering, construction, and generalization of stories in various situations. In addition, the concept of a dynamic memory is applied to the formulation of case-based reasoning (Riesbeck & Schank, 1989) as a model for solving a new problem using a previous similar episode (a case and its solution).

In several recent studies on cognitive architecture, the psychological concept of episodic memory (Tulving, 1983), which refers to the memory of one's past experiences, has been adopted in cognitive architectures. In particular, the Soar cognitive architecture (Laird, 2012; Nuxoll & Laird, 2007) includes episodic memory as one of the knowledge elements. Although the Soar episodic memory is only a snapshot of the virtual environment at each time step, the knowledge representation of an episodic memory is discussed in terms of a narrative or story (Anderson, 2015; León, 2016a; Szilas, 2015). León (2016a) proposed a graph-based knowledge representation of a narrative-form memory, including episodic and procedural memories. In addition, he modeled the production of an episodic narrative as a type of narrative discourse generation based on an episodic memory. In addition to concrete episodic knowledge, generalized schematic knowledge is an important element for human-like AI. For example, León (2016b) addresses the computational modeling of script construction.

Although autobiographical memory (memory of past information relevant to the self) and prospective memory (memory of future actions to be done) are well-known concepts in psychological studies on human memory, there are few or no studies which introduce these concepts into cognitive architectures.

Stories and script knowledge are also considered as knowledge elements in common-sense knowledge resources. For example, Chambers and Jurafsky (2010) proposed a resource of script-like knowledge based on automatic learning from narrative texts. Singh, Barry, and Liu (2004) proposed the concept of an integration framework for ConceptNet, LifeNet, and StoryNet. ConceptNet is a large-scale semantic network of concepts. A concept corresponds to a word or a phrase, and its semantic knowledge is represented based on its relation to other concepts. StoryNet corresponds to a database of small stories. A story is stored as simple sentences representing a sequence of events. In the integration framework, ConceptNet and StoryNet are connected in a type of complementary relationship. A story in StoryNet forms concretely contextualized knowledge of events. Concepts in ConceptNet are linked to stories that provide abstract or general semantic knowledge.

Story as the representational aspect of narrative: From a narrative-communication perspective

As described above, the knowledge aspect of narrative has been studied from a functional perspective. However, this knowledge aspect is rooted in the close relationship between the narrative and the method of organizing experiences into a mental representation. In this section, based on our previous formulation (Akimoto, 2018), we introduce the notion of "story" to refer to the representational aspect of a narrative.

Story as representation and discourse as expression

To clearly distinguish the representational aspect from an expressed narrative, we apply the notions of "story" and "discourse" in narratological[1] terminology (Genette, 1980; Prince, 2003). According to Prince's "a dictionary of narratology" (Prince, 2003), a narrative refers to an expression of events in a real or fictional world based on a language or other sign system. In narratology, the terms story and discourse are generally used to distinguish between the content and expression planes of a narrative. Namely, a story refers to the content plane of a narrative and a discourse refers to the expression plane of a narrative.[2] In other words, a discourse is the narrative text itself and a story corresponds to the content, i.e., the chronological organization of events recounted in the text. However, because a story is immaterial, the notion of story is slightly unclear.

From a narrative-communication perspective, the relationship between the content and expression planes of a narrative can be reinterpreted as the relationship between mental representations and the surface expression, as illustrated in Fig. 1. Stories between the sender (author or teller) and the receiver (reader or hearer) are not the same objects. On the sender side, a story corresponds to the source information of the expressed discourse, which is remembered or generated inside one's mind. On the receiver side, a story is also mentally constructed through interpreting or understanding the discourse expressed by the sender. For example, when a sender tells a receiver of his/her past experience, the sender's story corresponds to an episodic memory, and the receiver's story is made by interpreting the expressed discourse.

Basic story structure

In general terms, a story refers to chronologically organized events. This study assumes that a story represents a piece of a subjective world dominated by the temporal dimension, which is formed as a course of events. The entities' dimension, i.e., story world, is subordinated within the temporal dimension. Namely, a story contains a story world. We explain this using a simple example structure in Fig. 2. This story assumes a type of episodic memory of a boy named Taro. The story forms a course of events based on temporal and causal relations. The story world contained in the story forms the relational structure of the entities (characters, objects, and places) relevant to these events.

Although this example story shows a very simplified structure, a story is essentially a complex collection of information integrating events, entities, relationships, abstract concepts, intents, goals, emotions, and non-verbal information (e.g., memories of visual images). This type of multiplicity has been discussed from computational perspectives (e.g.Akimoto, 2018; Gervás & León, 2014; León, 2016a; Mani, 2013; Schank & Abelson, 1977). However, the computational modeling of a story structure with rich representational power remains a huge problem.

Subjective structures in stories

As we described in the previous section, a story is a mental object composed within the mind of an individual person or agent. The story itself does not exist in the external world. In this sense, every story is a subjective and individual object. For example, when several people watch a boxing match in a stadium, they will retain more or less different episodic memories (stories) based on their own experiences.[3] Although people cannot directly view stories inside other persons, their different stories are expressed in their discourses.

In this section, we address the conceptualization of how subjective

[1] Narratology refers to the discipline of theoretical studies on narrative, inspired by structuralism and semiology.

[2] Genette (1980) presented a general narratological theory of narrative discourse structure. From a computational perspective, Mani (2013) provides an outline of narratological concepts of narrative structure, including Genette's theory.

[3] However, background knowledge and the way of story making are partially shared with others through the cultural narrative experiences in their societies. In this sense, a story is essentially an intersubjective object.

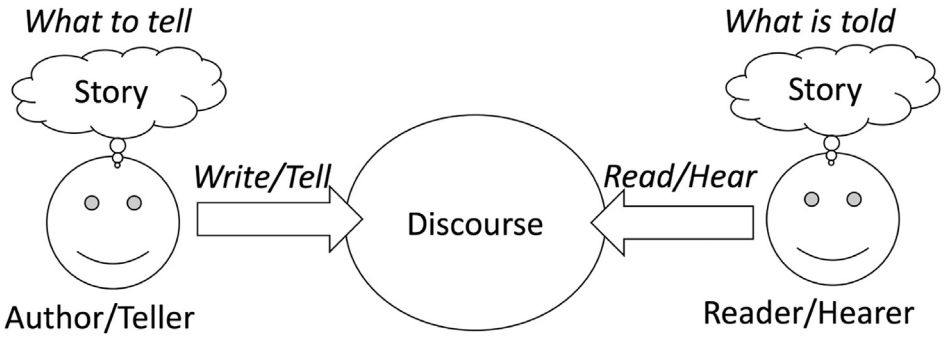

Fig. 1. Story and discourse from the narrative-communication perspective (Akimoto, 2018).

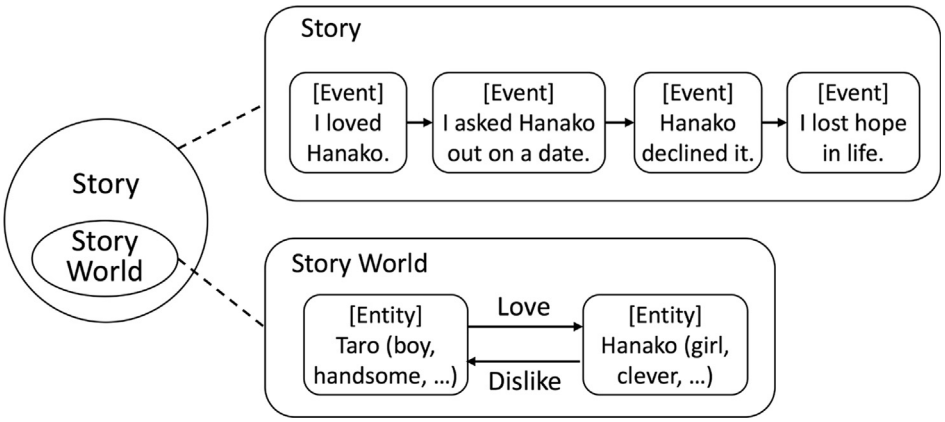

Fig. 2. Example structure of a story including a story world.

stories are structured in an agent's mental system. The following subsections present multiple structural aspects of subjectivity in an agent's stories.

Story of a current situation

A human being lives in a world with his/her own temporal extent across the past and future. For a human, a current situation (i.e., an external environment faced at a time point) is always experienced in a context. From a computational perspective, such a contextual structure of a current situation is mentally represented in the form of a story. The central character of the story is basically the agent itself. Hence, this type of story includes the agent's inner events, including sensory experiences and mental actions (e.g., intentions and emotions).

In a cognitive architecture, the story of a current situation will work as the integrated foundation of a higher-level perception–action system. Fig. 3 shows this concept. On the one hand, acting in an external environment is similar to performing mentally constructed events that are directed to the future. On the other hand, perceiving the movement of an external environment, including the results of one's actions, is similar to the construction of past episodic events. The important aspect of this perception–action cycle is that both perceptions and actions occur in the context formed as a story, i.e., a chain of events across the past (experiences and results) and future (expectations and plans). In the agent's mental system, the interaction with an external environment is based on the continual (re) construction of a story.

Association with past, future, and fiction

In an agent's mind, the individual special meaning of an object or an experience is formed by associating memories or imagined stories with the object or experience, beyond time and space. For example, a household agent that can generate subjective stories will view each family member as a special person by connecting past stories (memories) relevant to each of them. The basis of developing self-knowledge includes not only others' meanings, but stories about the agent itself, i.e., autobiographical memories.

This type of information is represented as a network among stories. Fig. 4 shows an example structure based on this concept. This example assumes that an agent is working in a room. As described in the

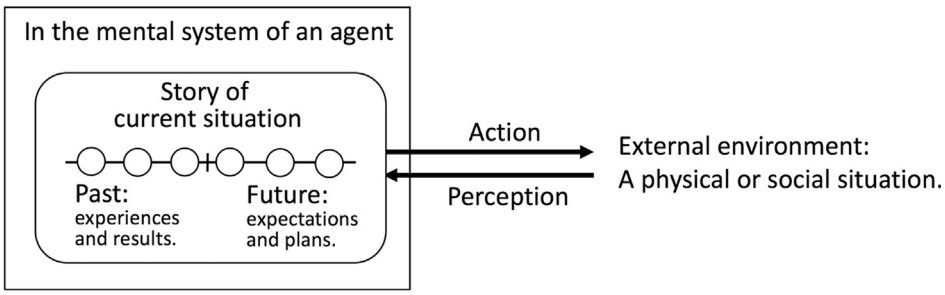

Fig. 3. Story as the basis of a higher-level perception-action system.

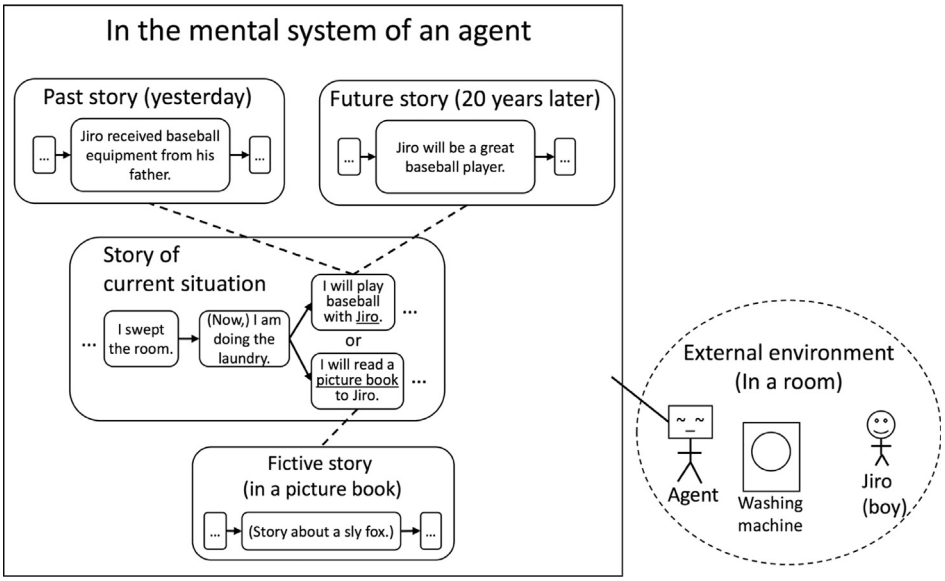

Fig. 4. Associating stories beyond time and space.

previous subsection, the current situation is formed as a story involving a short temporal extent. In addition, past and future stories relevant to Jiro, a character of the current story, are connected to the current situation. A fictional story (e.g., a memory of the contents of a picture book) can also be associated with a real object.

In addition, the ability to connect past, future, and fictional stories into a current situation is a cognitive foundation for directing future actions. For a human, the choice of actions in a social situation or the course of one's life is directed by various stories including past personal experiences, future visions, and fictional stories. Similarly, the agent develops a higher level of autonomy based on its ability to associate various stories with a current situation. In the aforementioned example (Fig. 4), the past story connected with Jiro will help the selection of a future action, i.e., what to play with Jiro.

Imagining mental stories about others

Imagining others' mental states, known as the theory of mind, is an essential characteristic of human intelligence. For an agent who constructs a subjective world using stories, a story is integrated mental information, including intents, desires, emotions, past memories, and plans. Thus, the ability to imagine (generate) a mental story about another person is a key element for advanced interaction with humans.

From a structural perspective, an imagined mental story about another person is represented as a nested story structure.[4] As we described previously, in an agent's mental system, another person is represented as a character in a story. An imagined mental story about another person is associated with that character. Fig. 5 shows an example structure based on this concept. In this situation, the agent is working in a room and is imagining a mental story about Jiro that means, "Jiro wants to play baseball with me (the agent)".

[4] In narratology, Genette (1980) conceptualized the notion of "narrative level" in a narrative discourse. The narrative level considers a type of nested structure explained as "a narrative (discourse) narrated within a narrative (discourse)". From a computational perspective, Lönneker (2005) addressed the formulation of a structural framework of a narrative level. Although the narrative level is a structural notion in the discourse (expression) plane, we assume that similar nested structures also exist in the story (representation) plane, explained as "a story within a story".

Distinction between fact and fiction

The cognitive mechanism of distinguishing between facts and fiction is important. A human naturally distinguishes between factual and fictive stories. For example, stories based on actual experiences, newspaper articles, and history texts are generally assumed to be facts and stories based on fiction novels, films, and virtual-reality contents are considered as fiction. However, a factual story for a human may change to a fictional story when they receive new information. For example, a newspaper article is sometimes exposed as a lie or an error. Hence, we assume that the distinction between fact and fiction is based on a personal or social belief that is represented by a type of meta-story information.

Discussion

A key point of our argument is that the cognitive mechanism for representing a subjective world using stories containing individual meaning and rich temporal extent is an essential element of a human-like and -friendly agent. In particular, this cognitive mechanism will be a common foundation for the following essential AI problems:

- Interaction with an external environment: Stories form a cognitive foundation for interacting with a social or physical situation. Stories construct a current situation with the contextual structure in which the past (experiences, results, and memories) and future (expectations and plans) are unified. Based on that contextual structure, the complexity of an external environment is reduced. For example, external information to be perceived and internal knowledge for interacting with an environment are restrictively organized by stories.
- Linguistic communication: A narrative is the universal mode of human linguistic communication. Modern humans communicate vast knowledge about a world through narratives in daily conversations, education, books, mass media, social media, etc. From a cognitive perspective, linguistic communications exchange information about a world (i.e., an external environment) between two or more closed mental systems. As we showed in Fig. 1, from the perspectives of both the sender and receiver, the information communicated by a narrative (discourse) is represented as a subjective story that is generated by a person's own cognitive ability. Hence, a subjective world formed by stories is a foundation of linguistic communication.

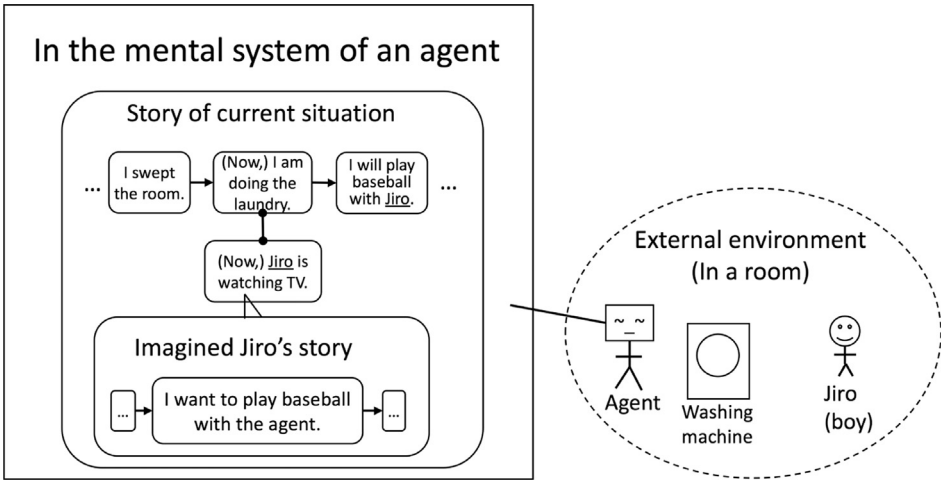

Fig. 5. Nested structure of an imagined mental story about another person.

- Individuality and similarity of world-views: Subjective stories, including individual memories and characteristics of a story-generation method, make an agent unique. However, a similarity of world-views between agents and humans is also important for their co-existence. Hence, mental stories and each agent's story-generation method should be developed through interaction with external environments, including communication with others in social situations. This cultural activity helps make them similar.

For these reasons, developing a computational model for dynamically generating and organizing mental stories is a crucial AI challenge. Computational narrative generation has been a very challenging problem for many years in AI. (Gervás (2009) provides a brief history of this area.) Although most previous narrative generation systems focus on the production of narrative texts, e.g., fairy tales and literary narratives, the heart of the problem is similar to a generative model of mental stories.

A major problem in the computational modeling of generative narrative cognition is that human narrative cognition is based on a vast store of experiential knowledge, including informal, tacit, and cultural knowledge. One accurate approach to this problem is to model generative narrative cognition based on the developmental process, as a human gradually develops his/her narrative ability through various social and physical experiences. This developmental process is modeled as a cyclic system of stories that reuse existing stories—which are generated through one's past experiences or cognitive activities—as the knowledge resource for generating new stories. Hence, cognitive mechanisms for flexibly reusing existing stories are required for the computational modeling of generative narrative cognition.

In particular, we can pose two key issues to be addressed, i.e., analogy and story generalization. Analogy is a general human cognition property for reusing existing representations (stories) to compose a new representation (story), beyond the problem domain (Gentner, 1983; Holyoak & Thagard, 1995). Case-based reasoning (Riesbeck & Schank, 1989) is also rooted in analogical cognition. Generalization or abstraction is also a general human cognition ability that forms general schematic structures (e.g., script knowledge) based on concrete experiences.

Conclusion

In this paper, we stated that a story is the uniform mental representation of a piece of a human's subjective world. A story as a mental representation is essentially a subjective and individual mental object that includes certain informational aspects. For example, a story forms a temporal organization of events, or a subjective meaning based on one's cognitive activities and memories. It organizes various types of informational elements, including events, entities, relationships, abstract concepts, intents, goals, emotions, and non-verbal information. Finally, a story is a cognitive basis of narrative, the universal mode of human communication. For these reasons, dynamic narrative cognition, based on a subjective world represented by stories, will provide a crucial foundation for a human-like and human-friendly agent. However, narrative cognition is a very complex problem for AI. Continual exploratory investigations based on a long-term vision are required.

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