

Exploratory Approach to the Computational Modeling of Narrative Ability for Artificial Intelligence

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Abstract—Narrative ability is an essential element of human intelligence from the perspectives of both psychology and artificial intelligence (AI). It includes many intellectual functions: narrative generation, narrative understanding or interpretation, narrative-mediated communication, and the manipulation of narrativity-based knowledge. The computational modeling of narrative ability is a critical problem in the development of human-like AI agents and user-friendly intelligent information systems. However, implementing this model involves many difficult challenges owing to the structural and phenomenal complexity of narratives. The broader purpose of this study is to develop a computational model of narrative ability from an AI perspective. In this study, we explore the formulation of a conceptual framework of computational narrative ability including a narrativity-based knowledge model and operational modules for this knowledge model.

Index Terms—Artificial intelligence, computational narrative ability, narrative agent, story-form knowledge.

I. INTRODUCTION

In this paper, we discuss the computational modeling of narrative ability from the perspective of artificial intelligence (AI). A narrative is a common mode of organically representing events in the real or fictional world. Narrative ability includes many intellectual functions: narrative generation, narrative understanding, narrative-mediated communication, storage of narrativity-based knowledge, and retrieval and use of that knowledge.

The importance of narrative ability or narrativity in the human mind and AI has been discussed from the psychological as well as AI perspectives [1]–[4]. From a psychological perspective, Bruner [1] explains that the human experience and cognition of the real world is based on narrativity and is formed as narratives. Schank and his colleagues proposed several AI theories of narrativity-based knowledge models including script, goal-plan, theme, and story [5]. They also formulated the concept of case-based reasoning [6] as a model for solving a new problem by using a previous similar case and its solution. Mateas and Sengers [3], [4] introduced the term “narrative intelligence” to describe a multiple research perspective on the relationship between narrative and AI. In studies on cognitive architectures, several researchers have been involved in the modeling of episodic memory [7]. Soar cognitive architecture [8], for example, has episodic memory as one of the knowledge elements [9], [10].

Furthermore, the knowledge representation of episodic memory is discussed in terms of narrative or story [11]–[13].

The computational modeling of narrative creativity, including its implementation, has long been a challenging problem in the field of AI. Many researchers have studied this problem from various perspectives, thoughts, and methodologies [14]–[18]. The theoretical background of these studies includes cognitive science on narrative, such as a story grammar [19], and narratology, such as Propp’s morphology of the folktale [20] and Genette’s narrative discourse theory [21].

Based on the above background, this study explores the computational modeling of narrative ability from the AI perspective. Although many challenging problems exist in the computational modeling of narrative ability, this study particularly emphasizes three aspects of narrative ability—*knowledge*, *communicative*, and *generative* aspects. These aspects will be crucial elements for implementing human-like AI agents and user-friendly intelligent information systems for the following reasons.

As described previously, the knowledge aspect of narratives has long been discussed by AI researchers. At the same time, a narrative is a universal mode for communicating knowledge or information. This will continue to be true in the context of human–computer communications. However, few studies describe the computational modeling of narrative-mediated communication that includes dialogue with humans. In addition, the generative ability or creativity of narratives is necessary both for generative processes of internally constructing narrativity-based knowledge and expressing narratives to others. Although many studies on the computational modeling of narrative creativity have been conducted as previously cited, these studies have been mainly focused on literary creativity or entertainment. We attempt to expand this accumulated knowledge to come up with a more general model for computational narrative ability as a basis for intelligence.

In this paper, we discuss the above problems for formulating a conceptual framework of computational narrative ability. We also show an architectural design of a narrative agent to perform prototyping of a part of computational narrative ability.

The rest of the paper is organized as follows. Section II discusses several potential approaches to computational narrative ability as a basis for general intelligence. Sections III and IV formulate the concept of a “story-form knowledge” as the knowledge aspect of narratives. Section V provides a framework of operational modules for the story-form knowledge as a basis for the various intellectual functions of computational narrative ability. Section VI shows the design

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of a narrative agent involving part of computational narrative ability. Section VII concludes this paper.

II. POTENTIAL APPROACHES TO COMPUTATIONAL NARRATIVE ABILITY

In this section, we consider several potential approaches to computational narrative ability from a long-term perspective.

A. Knowledge Sharing

Narrative is a universal and effective mode of human communication, and hence, computational narrative ability is an essential element of human-agent communication. In particular, the ability of composing narratives through editing the internal knowledge of an agent will be a key element in providing rich and valuable information to humans. Conversely, the ability of narrative understanding or interpretation is also necessary for gaining knowledge from human narratives.

B. Cooperative Problem Solving

Narrative generation is similar to problem solving. Planning a series of actions for solving a problem is a type of narrative or story generation. Actually, AI techniques of problem solving such as goal-based planning and case-based reasoning are among the major approaches to computational narrative generation [14], [15], [22], [23]. In the context of problem solving, computational narrative ability will be a basis for creating a narrative as a solution, proposing it to humans, and improving it through interaction with humans.

C. Cooperative Design

In a manner similar to that of cooperative problem solving, computational narrative ability will also be applied to the process of designing a complex artifact such as a city environment, software program, business plan, and service. For example, considering a quality user experience story is a crucial task for creating a better product [24]. This type of narrative is composed by harmonizing various values from multiple perspectives. An agent with high narrative ability will be able to support this type of narrative creation in design processes.

D. Constructing Identity

From the psychological perspective, narrative ability or narrativity is assumed an essential nature of the human mind. Experiences in the real world are integrated into a consistent narrative of one's life in the human mind and the identity is constructed by positioning oneself in this life story. However, this kind of narrativity is absent from the mind of current AI agents, as pointed out by Sengers [25]. Computational narrative ability is necessary for composing one's life story or episodic memory as the foundation of an agent's identity. Furthermore, the ability to recite past experiences to humans in the form of a narrative is also important.

E. Learning

Humans learn diverse knowledge from narratives and form their common-sense knowledge, which includes linguistic knowledge, ontological knowledge, social convention, causality, emotion, and ethics. Although many challenges of

learning from a huge amount of text data have been addressed in the area of machine learning [26], [27], the computational modeling of the knowledge aspect of narratives [2], [5], [28] will be a key problem related to the learning ability from narratives.

III. NARRATIVE AS KNOWLEDGE

A narrative generally refers to an output of narrating one or more events. Its expression media include natural language (utterance or text) and still or moving images. At the same time, narrative is also described as a comprehensive form of knowledge or memory. These two aspects, *expressed* and *internal* narratives, are illustrated in Fig. 1. This section discusses the knowledge aspect of narratives from the following two perspectives:

- 1) A. We discuss the difference between the expressed and internal narratives and introduce the term "story-form knowledge" for distinguishing them.
- 2) B. We provide a hypothetical classification of the story-form knowledge.

A. Story-Form Knowledge

In considering the difference between internal and expressed narratives, we refer to the narratological terminologies of dividing the content (or *what* to tell) and expression (or *how* to tell) planes of a narrative, i.e., a "story" (also known as a "fabula") and a "discourse" (also known as a "sujet") [21], [29]. These terms are also used in recent studies on the computational modeling of narrative [30], [31], especially in narrative generation systems [18], [32], [33].

A story (content plane) involves chronologically ordered events and its background world including entities such as humans, items, and places. In the discourse plane, one story can be expressed in various manners in terms of the temporal order (e.g., flashback and flash-forward), speed or tempo (e.g., summary and stretch), perspective or point-of-view, and so on [21].

From the perspective of knowledge representation, we assume that an internal narrative corresponds to the source of expressed narratives. It is similar to the story rather than the discourse. Therefore, we introduce the term "story-form knowledge" for referring to the knowledge aspect of narratives. However, an expressed narrative corresponds to a discourse; the generation of an expressed narrative for communicating story-form knowledge to others is formalized as a discourse generation.

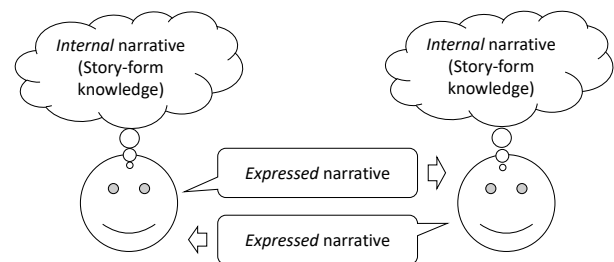


Fig. 1. Internal and expressed narratives.

B. Classification of Story-Form Knowledge

We assume that the concept of story-form knowledge can

be applied to several knowledge types. The previous studies on narrativity-based knowledge representation have mainly dealt in terms of an episodic memory or experience, procedural memory or script, and more comprehensive story [2], [5], [11], [12], [13], [28]. However, we focus on the manner of learning or constructing story-form knowledge and propose three knowledge types: *experience-based*, *narrative-mediated*, and *internally generated* stories.

1) *Experience-based stories*

An experience-based story refers to a story constructed based on one's own experiences in the real or virtual world. This is similar to the concept of episodic memory [7]. The *past* of an agent is formed by these stories.

2) *Narrative-mediated stories*

A narrative-mediated story refers to a story acquired from a narrative (e.g., novel, news report, conversation) as a human learns many stories from narratives beyond one's own experiences. This type of stories can be further classified into two types: *factual* and *fictional* stories.

a) *Factual stories*

Factual stories are collected from narratives about events in the real world. For example, the stories narrated in news reports and historical texts can be basically viewed as facts. Factual stories also include experiences of others told in their narratives.

b) *Fictional stories*

Fictional stories, including *realistic* and *unrealistic* stories, are collected from fictional narratives including novels, films, dramas, and computer games.

Note that the border of fact and fiction involves ambiguity. Factual narratives (e.g., news reports) may contain fictional stories including lies and errors. Similarly, fictional narratives (e.g., novels) may contain factual stories. Hence, we assume that the distinction between fact and fiction is basically left to one's interpretation. This hypothesis is also applied to the distinction between realism and unrealism.

3) *Internally generated stories*

An internally generated story refers to a story constructed inside the mind of an agent. This type of story includes *future*, *imaginative*, and *generalized* stories.

a) *Future stories*

A future story is similar to a plan for directing one's actions in the short- to long-term future. In many cases, future stories are constructed based on one's goals, desires, or dreams. The ability to produce future stories is a sign of intelligence relevant to problem solving by using techniques such as goal-based planning and case-based reasoning. The techniques of planning and case-based reasoning are also applied to narrative generation systems [14], [15], [22], [23].

b) *Imaginative stories*

An imaginative story refers to a fictional story imagined inside the mind of an agent. We assume that imaginative stories are mainly composed in creating fictional works of literature or other genres of narrative. In such cases, a created work corresponds to an expression of an imaginative story. In addition, daydreams are also included in this category (refer to [34] for an AI model of daydreaming).

c) *Generalized stories*

In general terms, a story basically has concreteness and specialty with specific events, characters, times, places, etc. However, schematic abstract knowledge models for constructing and/or understanding stories, including script [5], procedural knowledge [13], and story grammar [19], will also be assumed as types of story-form knowledge. These types of knowledge will be constructed through an abstraction or generalization of concrete stories including experience-based and narrative-mediated stories.

IV. REPRESENTATION OF STORY-FORM KNOWLEDGE

Next, we consider a structural model for representing the story-form knowledge. For this purpose, we apply a computational model of narrative structure representation as proposed in [35]. Although this model has been designed with a focus on the expressed narrative, we assume that a huge commonality exists between the internal and expressed narratives in their structures.

A. *Hierarchical Graph Model for Narrative Structure*

A hierarchical graph model for narrative structure representation is proposed in [35], in which various types of narrative units are organized hierarchically, with network-like linkages. It is based on the concept of object-oriented modeling. In this model, each of the story and discourse (in terms of narratology) aspects are further divided into two dimensions (see Fig. 2). In particular, a story consists of a *StoryWorld* and a *Story* (in a narrow sense) and a discourse consists of a *Discourse* (in a narrow sense) and an *Expression*. The four dimensions are defined below.

- 1) *StoryWorld*: The background world structure that contains information about entities (e.g., characters, objects, and places).
- 2) *Story*: The structure of chronologically organized events.
- 3) *Discourse*: The structure of how a *Story* is organized into a surface expression.
- 4) *Expression*: The surface expression using natural language, still or moving images, sounds, or other forms of media.

A *Discourse* is similar to the intermediate structure between content and expression. This type of intermediate structure is generally used in narrative generation systems as well as in natural language generation systems [36].

The hierarchical graph model is applied to each structural dimension of *StoryWorld*, *Story*, and *Discourse*. A hierarchical graph consists of three types of structural components: a semantic element (*SE*), a *Group*, and a *Link*.

- The *SE* contains semantic information for the basic unit in each structural dimension of a narrative.
- The *Group* integrates any number of nodes (*SEs* and/or *Groups*) into a broader unit. This function is similar to the linguistic abstraction or categorization of the member nodes. A *Group* itself has semantic information in the form of a comprehensive meaning that binds or abstracts the member nodes.
- The *Link* connects any two nodes with a relation or a set of connective attributes.

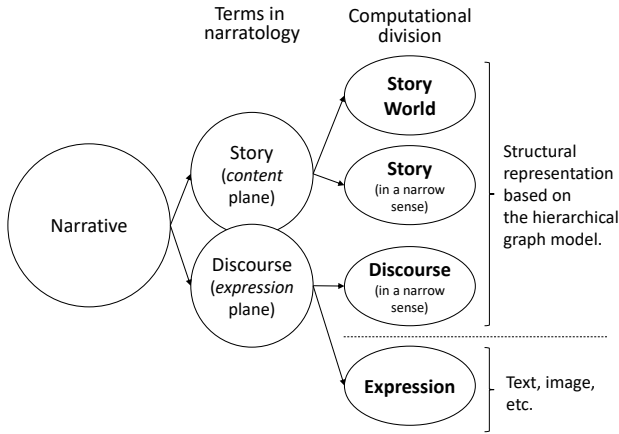


Fig. 2. Four dimensions of a narrative.

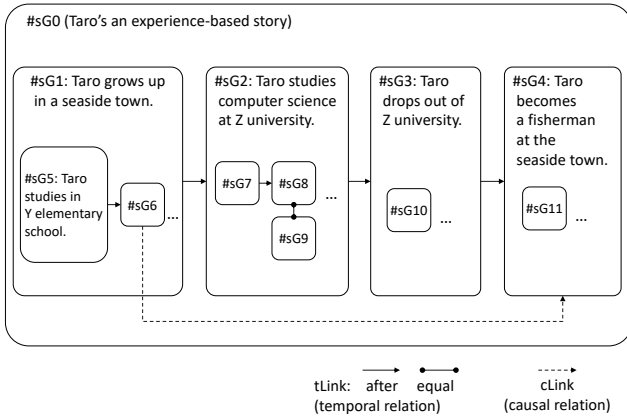


Fig. 3. An example Story structure for an experience-based story of an agent "Taro".

Although the components are commonly used in any structural dimension, the content of each type is different in every dimension. The subclasses of *SE*, *Group*, and *Link* for each dimension are defined in Table I.

B. Applying the Hierarchical Graph Model to Story-Form Knowledge

By using the above model, a unit of story-form knowledge, i.e., a story, can be represented as a pair of a *StoryWorld* and a *Story*. We use the term "k-story" for referring to this knowledge unit, in order to avoid confusion between a *Story* in the hierarchical graph model and a story as a knowledge unit. A knowledge base of story-form knowledge, referred to as "k-story base," stores a number of k-stories including experience-based, narrative-mediated, and internally generated stories.

Fig. 3 illustrates an example *Story* structure for a k-story. This k-story assumes an experience-based story of an agent "Taro." The attribute information of entities in this *Story* (e.g., "Taro," "Seaside town," "Y elementary school," and "Z university") are represented in the corresponding *StoryWorld* (we omit the explanation of this *StoryWorld* for simplicity).

The *Story* structure represents a temporal organization of events based on *sGroups* and *tLinks*. *tLinks* define the chronological order of events and *sGroups* form a temporal hierarchical segmentation of events from the summarized level to the detailed level.

Causality among events is also an important aspect for a k-story. This is defined by the *cLink*. In this example (Fig. 3), two *sGroups* "sG6" and "sG4" are related with a *cLink*. This

structure means that "#sG6"—an experience of "Taro" such as "Taro falls into the sea. An older fisherman rescues Taro. Taro expresses his admiration for the fisherman."—is positioned as the reason by which "Taro" becomes a fisherman ("sG4").

TABLE I: SUBCLASSES OF THE STRUCTURAL COMPONENTS OF THE HIERARCHICAL GRAPH MODEL

StoryWorld	Entity (<i>SE</i>)	An individual existence; for example, human, object, and place.
	wGroup	An aggregation of Entities/wGroups, such as a human group, a spatial unit, and functional kinship.
	wLink	A relation between two nodes; for example, interpersonal relations and spatial relations.
Story	Event (<i>SE</i>)	An action or happening.
	sGroup	An aggregation of Events/sGroups, such as a scene or a broader unit.
	tLink and cLink	A tLink is a relative temporal relation between two nodes for chronologically organizing a Story; for example, "before" and "equal." A cLink is a causal relation between two nodes.
Discourse	DU (<i>SE</i>)	A minimum segment of a Discourse.
	dGroup	A broader unit of DUs/dGroups as a semantic or formal segment of a Discourse.
	dLink	A pathway between two nodes with connective logic. That is, the threads of a narrative are composed using dLinks, defining the order in which the DUs are expressed.

However, the hierarchical graph model has several limitations. First, it lacks theories for representing one's subjective value or meaning of events and entities, such as the polarity and degree of importance of an event. This type of information will be positioned as an accompaniment to a node (*SE* or *Group*) in the hierarchical graph structure. Second, the hierarchical graph model cannot be applied to the representation of a generalized story (see Section III-B-3-c). Another representation model is required for generalized stories.

V. OPERATIONAL MODULES FOR THE STORY-FORM KNOWLEDGE

In this section, we consider the operational modules relevant to the story-form knowledge for performing various intellectual tasks. Totally, we provide six basic operations: *story generation*, *discourse generation*, *organization*, *retrieval*, *generalization*, and *narrative interpretation* (Fig. 4). The following subsections explain the role of each operation.

A. Story Generation

The function of the story generation module is to construct k-stories, especially experience-based, future, and imaginative stories in the aforementioned classification (Section III-B). An ability to generate future and imaginative stories is especially relevant to the creative aspect of intelligence. For example, it will be used in considering a

better future plan and plotting a unique story for an entertainment narrative.

We assume that the construction of experience-based stories involves subjective cognitive processes to integrate sensory information and create a consistent story. This process includes segmenting events from continuous sensory data [11] and relating among events. Therefore, the construction of experience-based stories is positioned as a function of the story generation module.

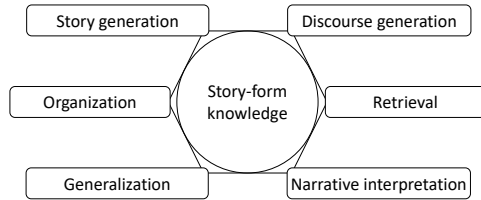


Fig. 4. Operational modules for the story-form knowledge.

B. Discourse Generation

The discourse generation module produces a narrative expression by using the k-story base with a communicative or creative goal. This module consists mainly of the following three generative processes: 1) retrieving one or more k-stories from the k-story base with the retrieval module, 2) composing a *Discourse* structure from the retrieved k-stories, and 3) generating a natural language text (an *Expression*).

In several studies on computational narrative generation [18], [32], [33], narrative discourse generation has been designed based on Genette's narratology [21] that systematically categorizes various classes of discourse structures through the analysis of a novel. These computational models commonly formalize the narrative discourse generation process with a set of transformational techniques from a story structure to a discourse structure. These computational methods can be applied to this discourse generation module, particularly to step 2 in the aforementioned procedure.

C. Organization

This module organizes a large amount of k-stories in the k-story base for increasing the accessibility for other modules. The types of knowledge organization may include network-like linkage among k-stories and hierarchical grouping of similar k-stories. This module also includes the function of forgetting k-stories.

D. Retrieval

The retrieval module searches for k-stories from the k-story base on request from other modules. For example, when an agent talks about a childhood episode, the discourse generation module will request a corresponding part of experience-based stories to the retrieval module.

E. Generalization

The generalization module constructs a generalized story from one or more k-stories in the k-story base. This module will be one of the basic elements for learning from narratives or experiences.

F. Narrative Interpretation

This module interprets an expressed narrative and

composes a k-story as the result. This module plays a key role in constructing narrative-mediated stories.

VI. ARCHITECTURE DESIGN OF A NARRATIVE AGENT: PLAN FOR A PROTOTYPE DEVELOPMENT

We plan to prototype a narrative agent as an implementation of a part of the computational narrative ability.

A. Outline

Fig. 5 shows an architecture design of the narrative agent prototype. This agent has the ability to tell k-stories in a k-story base through text-based dialogues with a human. The k-story base stores only experience-based and future stories, including one's goals, desires, and dreams. A human will understand or feel the agent's background, individuality, and personality through a dialogue with the agent.

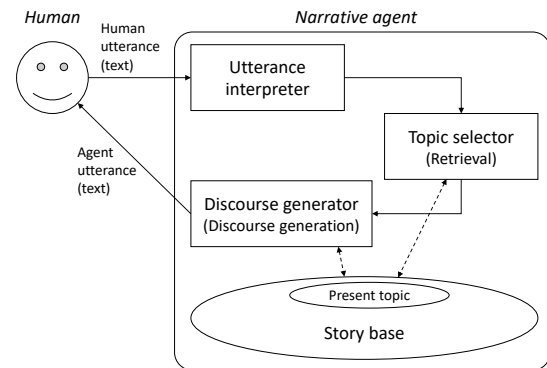


Fig. 5. Architecture design of a narrative agent.

The process flow of the narrative agent is summarized below:

Step 1. An utterance interpreter receives a human utterance (text) and analyzes it for determining queries to be used in the k-story base retrieval in step 2.

Step 2. A topic selector retrieves a node of a k-story (an *sGroup* or *Event* in the *Story* structure) from the k-story base according to the queries determined in step 1. The retrieved node is set as the present topic to be narrated in the next agent utterance.

Step 3. A discourse generator composes a *Discourse* structure by using the present topic and then generates natural language sentences (*Expression*) from the *Discourse*.

The generated sentences are presented to the human and the above processes are repeated until the human exits the dialog.

B. Main Problems

This prototype version implements the following three key functionalities of the computational narrative ability.

1) Modeling a knowledge representation for the story-form knowledge

We will implement a representation model of the story-form knowledge based on the consideration in Section IV. By using this model, a number of hand-created k-stories including experience-based and future stories are installed in the k-story base.

2) Implementing "retrieval" for the topic selector

A key function of the topic selector is to choose an

appropriate topic for an agent utterance according to a human utterance. For example, when the agent is asked by a human to talk about a childhood episode, the topic selector should retrieve a part of a k-story relevant to one's childhood experiences.

3) Implementing "discourse generation" for the discourse generator

In the simplest case, the discourse generator produces sentences in which the events of a selected topic (retrieved node) are plainly recounted in a chronological order. However, a significant role of the discourse generator is to narrate k-stories by various methods. In particular, we plan to introduce the following discourse techniques by referring to Genette's narratology [21].

- Temporal transition: The agent occasionally changes the present topic from the one selected by the topic selector to another topic in mid-sentence, by relating the two topics in an associative manner.
- Hiding: The agent occasionally omits negative events (or uncomfortable events to talk about, such as failures and crimes) from the present topic.
- Summary and stretch: The agent controls the detail level of narrating a topic by using the hierarchical grouping structure of the *Story*.
- Commentary and description: The agent describes not only events, but also commentaries or descriptions on humans, places, or other entities. For example, the agent first explains the key persons involved in the present topic.
- First-person: In agent's narratives, the agent himself is designated as the first-person.

VII. CONCLUSION

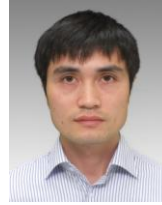
In this paper, we described the major problems encountered in the computational modeling of narrative ability from an AI perspective. We mainly discussed two aspects of narrative ability: the story-form knowledge that represents the knowledge aspect of narratives and the operational modules for the story-form knowledge that provide a basic framework for various intellectual functions of the computational narrative ability. We also described the prototype design of a narrative agent including part of the computational narrative ability.

Through these discussions, we provided the draft of a new research framework for the computational narrative ability. This framework is based on the reorganization of previous AI studies on narratives, especially narrativity-based knowledge models and computational narrative generation. Although many challenging problems were addressed in this study, narrative ability will be a crucial element for human-like AI agents. Our future work will involve prototyping a narrative agent and providing conceptual and architectural refinement to the computational narrative ability.

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