Understanding of Stories for Animation

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ABSTRACT
This paper presents the story understanding mechanism for creating computer animation scenarios. The story understanding mechanism reads a natural language story and creates its scenario for realistic graphic animations. This paper presents three types of hidden actions and relations of actions that must be discovered for realistic animations of stories but which are not explicitly described in the stories. They are: 1) causality check among actions; 2) interpolation of a continuous action beyond a sentence; 3) interpolation of hidden actions between neighboring sentences. This paper also describes the inference mechanism which recognizes the need for interpolation of these hidden actions. Multiple TMS is introduced in the mechanism. The knowledge base is action-oriented, hence it is independent of individual stories’ domains.

1. Introduction

Recently computer animations have been widely used in many fields like conventional CAD, commercial films and movies. For these kinds of applications, high-level languages are now provided [Reynolds 82][Zeltzer 82]. However, because these languages are programming languages and are hard to use for untrained personnel, it is desirable to develop an easy-to-use computer animation system to encourage more wide-spread use of computer animation.

The authors have been developing Story Driven Animation (SDA) [Takashima et al. 87] which automatically generates the animation for a given story written in Japanese taken from a children’s story book.

SDA consists of three modules: 1) story understanding; 2) stage directing; 3) action generating. The first module reads a story written in Japanese and makes an action-based scenario. The second module receives the scenario and modifies it for stage setting. The last module generates animations on a graphics display according to

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the precisely specified scenario given by the stage directing module.

SDA differs from previous natural language processing systems, such as summarizing [Young & Hayes 85][Lytinen & Gershman 86], depth understanding of stories [Dyer 83], question-answering [Wilensky 82][Harris 84] and story generating [Schank & Riesbeck 81], in that it interpolates hidden actions among sentences that must be discovered for realistic computer animations but are not explicitly described in the story itself.

Since SDA can accept curtailed expressions in input stories, story writers do not have to describe all the acts explicitly to get the desired graphic animation. Consider the following sentences in "The Hare and The Tortoise" in Aesop’s fables:

(1). The hare ran.
(2). The hare looked back.
(3). The hare said, “the tortoise can never catch up with me”.
(4). The hare lay down on the grass.
("The Hare and The Tortoise", Aesop's fable)

It is never thought that the hare would lie down while running with his face looking in the reverse direction. If he were to do so, he would do a dive and his neck would be broken! Any person can conjure up an accurate image of the hare’s actions. Naturally lacking facts between sentences are interpolated using the human reader’s common-sense. We imagine that the hare stopped between (1) and (2), and looked forward between (3) and (4). However, if an animation producing program does not have this common-sense, it produces strange graphic animations when these sentences are not more explicitly described. The above scenario is merely one example of SDA’s ability to interpolate curtailed expressions of action. In order for a story understanding program to accurately accept input sentences, it is imperative that such a common sense be built into the program.

SDA story understanding mechanism was constructed based on action-oriented knowledge. Knowledge related to actors’ actions is independent of the content of individual stories, and is common to

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everyone since actors' movements are constrained by physical limitations of a human body. Although this story understanding approach is superficial, it allows for an extensive domain.

This kind of research which strictly infers occurrences of actions among natural language sentences has not been done yet. In this paper we present various types of hidden actions among sentences and the inference mechanism to identify and interpolate them. The whole SDA system is roughly described in [Takashima et al. 87].

2. Types of Hidden Actions to be Interpolated

There are three types of hidden actions and relations of actions to be interpolated among sentences. The above example shows a type of hidden actions to be interpolated. It can be stated as follows:

- Continuity of different actions between sentences: When an action in a sentence is not consecutive to any action in the previous sentence, bridging action(s) has/have to be found and added into the original text. The action "stop" between "run" at (1) and "look back" at (2) and the action "look forward" between "look back" at (2) and "lie down" at (4) are examples.

SDA interpolates discriminately; if in the same context it must interpolate, if not in the same context, then it must not try to interpolate (e.g. "The frog lay down. The next morning, the frog went out.").

The following example includes the other two types of interpolations in it. The example is also from "The Hare and The Tortoise".

(5). The tortoise ran.
(6). The tortoise ran as kicking up a cloud of dust.
(7). The tortoise sweat while running.
(8). The tortoise stopped at the top of the mountain.

The proper interpretation of these sequences may be the followings:

The tortoise starts running at (5). The tortoise runs while kicking up a cloud of dust at (6). Here, the action of "kick-up-a-cloud-of-dust" must be caused by the action of "run". The tortoise sweats while running and kicking up a cloud of dust at (7), even though "kick-up-a-cloud-of-dust" is not specified in (7). Here, the action of "sweat" must be caused by the action "run", for the tortoise is not breaking into a cold sweat. The tortoise stops running at (8). At this time the tortoise also stops "kick-up-a-cloud-of-dust"-ing and "sweat"-ing because these two actions were caused by "run".

The other two types of hidden actions are:

- Causality among actions: When an action appears in a sentence, it must be verified whether it is independent of any other action or caused by other actions. If an action is caused by another action, it also ceases when its dependent action stops, (e.g. the relationship between "kick-up-a-cloud-of-dust" to "run" and "sweat" to "run"). This verification is done between neighboring sentences whose agent is the same.

Continuity of an action beyond a sentence: An action is assumed to continue until it is explicitly ordered to stop if this action is a continuous type. Inference of the continuity of the action "kick-up-a-cloud-of-dust" from (6) to (7) is an example.

3. SDA Story Understanding Mechanism

In order to accurately understand an input story, SDA performs four distinct operations:

[1] Extracting meanings of a sentence: Each sentence is parsed, its meanings extracted, and the meanings put into an independent block called world. Because our target story has a simple form, the sequence of its sentences becomes a chronological sequence. Each sentence in a story includes several assertions. An assertion extracted from a sentence may not be true in context with time of its succeeding sentence. Therefore, an individual world is assigned to each sentence in order to store assertions which represent the situation inherent in a sentence. When a new world is created, it is linked to the sequence of worlds which is linked with each individual actor; the hare, the tortoise etc. Each world is compared with its previous world, and its assertions are added/deleted/modified in the following processes, [3] and [4].

[2] Causality check among actions: When an action assertion is put into a world, its causal relationship to other actions is checked. If it is dependent on another action, the causality link is connected between the action and its independent action.

[3] Interpolation of hidden actions between neighboring sentences: Each action of the present sentence is also checked for its continuity to actions in the previous world. If some action is hidden between the previous world and this sentence, it is identified and added into the present world.

[4] Interpolation of a continuous action beyond a sentence: When there exist actions which are not mentioned in the present sentence but should continue from the previous sentence to the present sentence, they are added into the present world.
Implementation

4.1 Implementing world

Each world consists of two stages: present-state and post-state. Present-state, the upper part of a world, holds assertions which represent the state of the moment when the sentence is uttered. Post-state, the lower part of a world, holds assertions which represent the state just after the time when the sentence is uttered. For example, the world of (5) has the assertion "the tortoise runs" in its present-state, the assertion "the-act-of the tortoise is run" in its post-state (see Figure 1).

| the tortoise runs. | present-state |
| the-act-of the tortoise is run. | post-state |

Figure 1 World of (5)

This means that the tortoise is running during the sentence (5) and afterwards continues to run. Each post-state of each world is independently monitored by Truth Maintenance System (TMS) [Doyle 79]. This structure is similar to Viewpoints in ART [Clayton 85]. TMS works well in accomplishing the continuity check of an action beyond a sentence.

4.2 Causality Check Among Actions

The dictionary contains action causalities of verbs. When a verb or a verb phrase is processed, the SDA parser consults the dictionary. The following is a part of the dictionary for the verb phrase, "kick-up-a-cloud-of-dust":

kick-up-a-cloud-of-dust
if the-act-of *actor is run then
  present-state: *actor kick-up-a-cloud-of-dust.
  post-state: true(the-act-of *actor is kick-up-a-cloud-of-dust) supported-by
    (in the assertion-id of "true(the-act-of *actor is run")
    out())
else
  present-state: *actor kick-up-a-cloud-of-dust.
  post-state: true(the-act-of *actor is kick-up-a-cloud-of-dust) as-premise

If the tortoise kicks up a cloud of dust when it is running, the action of "kick-up-a-cloud-of-dust" is assumed to be caused by the "run" action. Therefore, the corresponding assertion of the action "kick-up-a-cloud-of-dust" is supported by the "run" assertion. If the tortoise is not running at the time, the assertion of "kick-up-a-cloud-of-dust" is justified as a premise, which means that the tortoise is kick-up-a cloud of dust while standing at a point. This causality between different actions is used as a dependency directed link for TMS.

4.3 Interpolation of Hidden Actions Between Sentences

Interpolation of hidden actions is accomplished by using goal directed search. When a sentence is processed and its assertions are extracted, the system picks up each assertion, and then makes an inspection to determine whether the action of each assertion is continuous from the state of the previous world or not. The continuity is inspected by checking whether the pre-condition of the action is satisfied in the post-state of the previous world or not. Each verb is specified its pre-condition and post-condition in the dictionary. Pre-condition is the constraint to be satisfied just before the act of a verb. Post-condition is the state to be achieved just after the act of a verb. For example, the dictionary indicates that in order to "stop", the agent must be going on foot (pre-condition), and after the agent "stop"s, it must be standing (post-condition).

If an action in the present sentence is continuous from the post-state of the previous world, it is simply put into the present world. If it is not continuous, the system searches for a sequence of actions which bridge it (goal point) and the post-state of the previous world (starting points) by referring the pre-condition/post-condition of verbs in the dictionary. This search process is similar to the execution of STRIPS [Nilsson 80]. If a bridging sequence of actions is found, the abridged actions in the sequence are added into the original assertion. Then, the modified assertion is put into the world.

The sentence (2) "the hare looked back" is modified to "the hare stopped and looked back" in order to satisfy the pre-condition of the verb phrase "looked back". The related pieces of the dictionary are shown below.

look-back

pre-condition:
  (the-state-of the agent is not in the reverse direction
  OR
  nothing is mentioned regarding the direction
  )
  AND
  the-state-of the agent is standing.

post-condition:
  the-state-of the agent is in the reverse direction.

stop

pre-condition:
  the-act-of the agent is go-on-foot.

post-condition:
  the-state-of the agent is standing.
4.4 Interpolation of a Continuous Action Beyond a Sentence

Interpolation of a continuous action beyond a sentence is accomplished based on the assumption that actors' actions are assumed to continue until they are explicitly ordered to stop. This assumption is the same as the persistence problem in [Shoham 88].

After a sentence is analyzed and its meanings are stored into both the present-state and the post-state of the present world, all the assertions in the post-state of the previous world are copied into the post-state of the present world. Then, the post-state of the present world is checked its consistency by TMS. This check prevents the over-copying of continuous actions from the previous world. TMS works according to the following monitoring rules:

- Duplication Elimination Rule: If there exist two or more same assertions in the present world, the copied one from the previous world is eliminated.
- Exclusive Action Elimination Rule: If there exist exclusive assertions, the one copied from the previous world is eliminated. The exclusion relations of actions and states are also defined in the dictionary. The exclusion relations are like the followings:
  exclusive(act-of run, state-of standing)
  exclusive(act-of run, act-of walk).

TMS compares each of the assertions in a world with each other. If two assertions cannot coexist, the one copied from the previous world is deleted.

Figure 2 shows the worlds corresponding to sentence (6), (7) and (8).

Here, the world of (6) is already truth-maintained. After the sentence (7) is analyzed and its meanings are stored into the world of (7), the two assertions in the post-state of (6) are copied into the post-state of (7). TMS then deletes the duplicated assertion, "the-act-of the tortoise is run". The assertion "the-act-of the tortoise is kick-up-a-cloud-of-dust" remains in the post-state of (7).

Generally an assertion in a post-state corresponds to an assertion which presents the causal action in a present-state of the same world. For example, "the-act-of the tortoise is run" is corresponding to "the tortoise runs". When an assertion is added into the post-state of the present world by copied from the previous world and has no correspondence in the present-state of the present world, its corresponding assertion is created and put into the present-state of the present world by the system. Therefore, in this situation the corresponding assertion, "The tortoise kick-up-a-cloud-of-dust" is created and added into the present-state of (7). The present-state of world of (7) shows that the tortoise is running while sweating and kicking up a cloud of dust (present-state), and afterwards continues to run while sweating and kicking up a cloud of dust (post-state).

After the meanings of the sentence (8) are stored into the world of (8), three assertions are copied from the world of (7) to the world of (8). Next, because "act-of run" and "state-of standing" are exclusive, the assertion "the-act-of the tortoise is run" is deleted by TMS according to the exclusive action elimination rule. Then, two other assertions in the post-state of (8) which were supported by the deleted assertions are subsequently eliminated according to the dependency-directed backtracking mechanism of TMS. Now, the world of (8) has only one assertion, "the-state-of the tortoise is standing", in the post-state of (8), which means the tortoise is standing and stopped kicking up a cloud of dust and sweating.

After all the story is processed and represented as chronological sequences of worlds, assertions in the present-state of each world are gathered and transformed into a scenario for the stage directing module.

5. System Configuration

Figure 3 indicates a high level view of the whole story understanding system. Each sentence is processed individually and its assertions are extracted by SENTENCE-PARSER. The sentence grammar in SENTENCE-PARSER is described using Definite
Clause Grammar in Prolog [Pereira & Warren 80]. The assertions are then put into the MORE-MEANING-EXTRACTOR which is based on forward-reasoning. Here as many assertions as possible are extracted from the inputs. For example, "If the weather is fine and it is night, then the background for the drama stage is colored in black with lots of stars", etc. The extracted assertions are put into a separate world for each sentence. Each world is monitored by TMS. Path #1 between neighboring worlds indicates the interpolation of a continuous action beyond a sentence. Path #2 indicates goal directed search to discover the path of transition between different actions. The whole story understanding system is implemented using Prolog on vax11/780.

6. Conclusion

This paper presents the story understanding mechanism for creating computer animation scenarios. The story understanding mechanism reads a natural language story and creates its scenario for realistic graphic animations. This paper presents three types of hidden actions and relations of actions that must be discovered for realistic animations of stories but which are not explicitly described in the stories. This paper also describes the inference mechanism which recognizes the need for interpolation of these hidden actions and relations. The transition in a story is reflected by chronological sequences of multiple worlds, each of which is monitored by TMS. A world holds extracted assertions representing the situation inherent in a sentence. Each world is compared with its neighboring worlds, and assertions in the world are added/deleted/modified in the following three processes:
- Causality check among actions.
- Interpolation of a continuous action beyond a sentence.
- Interpolation of hidden actions between neighboring sentences.

The knowledge base is action-oriented, hence it is independent of individual stories’ domains. Currently, the story understanding mechanism works well for several fables.

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Figure 3 Whole Story Understanding System
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