An Ontology Model for Narrative Image Annotation in the Field of Cultural Heritage

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Abstract. Traditional event models couldn't model temporal-spatial information very well in narrative image tagging task especially in the field of culture heritage. In this paper, we design a narrative image annotation ontology (NIAO) model and tool (NIA) to address this issue by using ontology design patterns and other related vocabularies for reusability. The annotation model, combining with OAC (Open Annotation Collaboration) framework and regarding Plot as central class, makes a mapping between annotated image regions and high-level image semantics. It has been embedded in NIA which is designed based on html5 and applied in annotation task of narrative paintings successfully. This tool can record annotation region pixels and related property values according to NIAO, and these annotation data can be stored as various formats such as csv, json, and rdf. We have built a SPARQL endpoint, in which end users can make semantic queries based on these annotation data for visualization of the results with pictures rather than tables.

Keywords: Image annotation, Narrative image, Plot ontology

1 Introduction and Motivation

A narrative [2,7] is a general unifying framework used for relating real-life or fictional stories involving concrete or imaginary characters and their relationships. A narrative consists of work of speech, writing, song, film, television, video game, photography, theater, etc. According to this definition, narrative image is a kind of image with stories behind it, like Figure 1. It is a mural image, and the original mural was located in No. 257 Mogao cave in China. This image content is about a Jataka tale of the nine colored deer which can be simply described as the following words.

> *The nine colored deer saved a drowning person when it walked along a river. The drowning person gave his thanks to the deer on his knees, the deer told the drowning person not to leak its location. At the same time, in the palace, the queen talked about her dream about a nine colored deer to the king. When the drowning person came back home, he told whereabouts of the deer to the king and queen. Then the king made an order to hunt the deer. At last, the deer got caught and confronted with the king, it told the cause of the whole thing. Finally the drowning person got punished due to his dishonest.*

The mural painting clearly describes a multiple plots story across multiple time and space. In a scene of cultural heritage collection exploration, when unprofessional people look into these narrative paintings or their related images, they want to know the stories behind these images. We need a kind of "guide interpreter" who can tell these stories and know corresponding image region related to each story plot during narrating. For artists, historians or painters, they also want to get some useful information from these paintings such as painting skills, narrative way and characters, actions etc. in details. Due to the lack of labeled images in specific cultural heritage field, traditional machine learning or deep learning techniques are incapable of learning fine-grained narrative knowledge from this kind of images, and the common event models given in Section 2 are also have some limitations in dealing with continuity of plot and abstraction of temporal-spacial information for narrative image annotation to some extend.

Fig. 1. Jataka Story about the Nine Colored Deer

We have already got some requirements focused on narrative images by analysing a set of scenarios from domain experts especially in the field of Dunhuang paintings[3]. And some of these requirements are organized and expressed using competency questions (CQs) [6].Such as: What's the story behind this image or painting? How did this story happen according to this image? Which plots of this story happened at the same time with others? What kinds of entities or persons appeared in this plot or story? What did they do in this plot or story and who is actor, who is recepient? Which entity appear in more than one plot? Are there some plots overlapped with each other in this image? ,etc.

It has capability to deal with complex knowledge representation, and meanwhile make them findable and be integrated into other applications easily by using ontology and semantic techniques. So in this paper we has designed an ontology model and annotation tool of narrative image to represent narrative knowledge in semantic way to satisfy users' requirements. The structure of this article is described as follows: in Section 2, it describes the relevant studies of event or narrative models. In Section 3, the narrative image annotation ontology (NIAO) was built, including concepts and properties; Section 4 shows the availability of this annotation model by tagging an image using NIA; Finally, this paper summarizes the challenges and future research plans in the application of NIAO.

[3] You could find some examples at `http://www.e-dunhuang.com/index.htm`

2 Related Works

At present, studies about narrative image is mainly focused on iconography and culture art history. Study of narrative image semantic annotation is rare. In 2016, Microsoft released a narrative image dataset named VIST sequential vision-to-language[4], whose purpose is to explore how this dataset may be used for the task of visual storytelling.

Some event or narrative models are also developed during this years. Event ontology[5] is a common and simple rdf model for event in which *sub_event* is used to represent events' relationships. It also can be combined with Timeline ontology [6] to annotate sections of a signal, a video, or any temporal object. Tuffield [17] took Bals layered view of narrative [2] as the way to understand what is being modeled, namely Fabula, Story and Narrative itself. Stories Ontology [13] was built upon the oft-used Event[7] and Timeline[8] ontologies. The core classes and attributes include such as *Story*, *EventSlot*, *slot*, *substory* and so on, but its short of interface for story participants. Literature [12] gave an OWL format Storytelling Ontology, in which story is regarded as a sequence of events. However Rhetorical Structure Theory [10] which focused on text organization used in this model makes it not suitable for describing narrative images. Fabio Ciotti [3] proposed a narrative ontology, which contained *Actant*, *Action*, *Actor*, *Event*, *Quality*, *Object*, as its core elements, but it didn't have related properties to represent the continuity of narratives. Rossana Damiano [4] proposed a top-level narrative and action ontology. It is a very good model that contains all information that narrative or event should have, but it also didnt pay attention to relationships between sub-stories or sub-events.

The ABC Ontology [9] is a similar model. In this model, sub-events' relationships are represented by using *Situation* as intermediary and properties like *follows* and *precedes* are also designed to express this relations. This is a good choice to represent relationships between sub-events, but it is not a intuitive and direct way for users. The BBC's storyline ontology [14] is used to organize news events, and it uses *follows* to represent temporal relationships between *StorylineSlot*, but in the narrative media objects, relations are not only this types. VU University Amsterdam also developed a Simple Event Model (SEM) [18] which uses *hasSubEvent* to represent the part-whole relations between *Events*. It has similar limitations to [14] for narrative image annotation. Like [18], the activity ontology [11] use *hasSubActivity* to represent relationships between activities. And in [8], *SubEventOf* property is used to express events' relationships. LODE [16] provides interaction function between existing event models whose aim is to make information access between various event models more conveniently. Event-model F [15] also provides *event*, *location*, *time*, *participant* and

[4] See `http://visionandlanguage.net/VIST/`
[5] See `http://motools.sourceforge.net/event/event.html`
[6] See `http://motools.sourceforge.net/timeline/timeline.html`
[7] See `http://motools.sourceforge.net/event/event.html`
[8] See `http://motools.sourceforge.net/timeline/timeline.html`

other types of modeling capabilities, and it took an Ontology Design Pattern (ODP) development approach to increase its scalability and reusability.

There are lots of other ODPs related to event models in the web site `http://ontologydesignpatterns.org/wiki/Main_Page`, such as EventCore[9], Event-Processing[10] and other patterns such as Participation[11],Situation[12], `Time_indexed_person_role`[13] and so on that can be used in event modeling. We will not go further into them but some of them will be used in our model in later section.

These models and patterns have their own advantages and characteristics in respective fields and applications, but in the field of cultural heritage image annotation, there are some limitations among them. On the one hand, information about time and space is relatively vague, such as *morning* or *mountain*, we couldn't get precise information about what's the exact year or what's the exact place from these words derived from paintings usually. These information is too vague to use existing narrative or event model extensions to represent in this kind image. At the same time, relationship representation among plots is not rich enough when using these event models. On the other hand, since there is no interface for image annotation, existing narrative or event models cannot be directly applied in the process of image annotation task.

3 Narrative Image Annotation Ontology

3.1 Methodology

NIAO is designed by reusing existing ontologies or vocabularies and pattern-based ontology engineering aimed at extensively reusing ODPs for modeling ontologies.

We extracted a set of requirements expressed in terms of CQs. Then we extracted a set of concepts and properties that provide the basic building blocks for dealing with knowledge within the field of narrative images. After that we identified the most appropriate ODPs and other related ontologies or vocabularies from the on-line repository `ontologydesignpatterns.org` and some of the above mentioned studies. The ODPs resulting from the previous step are modeled in NIAO by means of specialisation. However, we do not directly import any specific implementation of ODPs in our ontology, in order to be completely independent of them. At the same time, other existing ontology vocabularies such as CIDOC CRM [5] are also used in our model.

3.2 Plot in Narrative Image

Figure 1 is a digital image and it is also a *crm:Man_Made_Thing* shot with an equipment on mural painting in the cave by a photographer. Some metadata

[9] See `http://ontologydesignpatterns.org/wiki/Submissions:EventCore`
[10] See `http://ontologydesignpatterns.org/wiki/Submissions:EventProcessing`
[11] See `http://ontologydesignpatterns.org/wiki/Submissions:Participation`
[12] See `http://ontologydesignpatterns.org/wiki/Submissions:Situation`
[13] See `http://ontologydesignpatterns.org/wiki/Submissions:Time_indexed_person_role`

can be used to describe the *crm:Man_Made_Object* namely the Mural and the related digital image. Digital image has its own semantic content from its related art Work including the *type* of mural, the *subject* of the story behind, *characters* and *animals* in it, *environment*, *action*,*plot* and other a series of abstract *crm:Concept_Object*.

In this paper, we annotate *crm:Concept_Object* in narrative images like Figure1. Proposed in the literature [19], semantic description of main components of digital image are like *Object*, *Object space*, *Scene* ,*Behaviors/Activities*, *Sentiment* etc. For narrative images, space and time relations namely *Plot* among above concepts as another element are added into image annotation task.

Plot can be seen as a *crm:Conceptual_Object* collection, and there exists chronological relations between sub-plots. Plot is a process of a change, so *plot* has specific situation of time and space, and through the spatial-temporal information, a *plot* can be contacted to other *plots*. Plot in narrative image is usually characterized by an *Action* or *Behavior* and other dynamic elements, such as running, singing, and natural phenomena such as water flowing, raining, earthquake and other external trigger elements.

3.3 Classes and Properties

OAC(Open Annotation Collaboration)[14] as a bridge framework for media annotation is used in our model for connecting image annotation task and plot modeling.

In OAC, the annotated resource is an *Annotation* type, and this Annotation can connect more than one *Body* and *Target*, which are the vocabularies used in actual tagging process. The content of the *Body* resources is related to, and typically "about", the content of the *Target* resources. Annotations, Bodies and Targets may have their own properties and relationships, typically including creation and descriptive information.The Target resource is always an external web resource, but the Body may also be embedded within the Annotation. *crm:Concept_Object* in image can be connected to *Body* through *niao:referTo* property, so we add *Plot* as a reference to *Body* for extension.

```
<http://niao.whu.edu.cn/anno1> a oa:Annotation;
    oa:hasBody <http://niao.whu.edu.cn/body1>;
    oa:hasTarget <http://niao.whu.edu.cn/thing1>;
<http://niao.whu.edu.cn/body1> niao:referTo <http://niao.whu.edu.cn/plot1>;
<http://niao.whu.edu.cn/plot1> a niao:Plot;
```

The entire narrative image Plot model is shown in Figure2. There are chronological and overlapping relationships between plots and their related image regions. A *plot* occurred (*hasSetting*) in a particular situation (*Context*), and *plot*s have some *entities* involved in, such as *Person*, and other objects. A plot represented in image region usually combined with dynamic elements (*Dynamics*) to show dynamic development characteristics of the plot, such as *Action* of participants in plots. The core classes of this model are described below.

[14] See https://www.w3.org/TR/annotation-model/ and https://www.w3.org/TR/annotation-vocab/

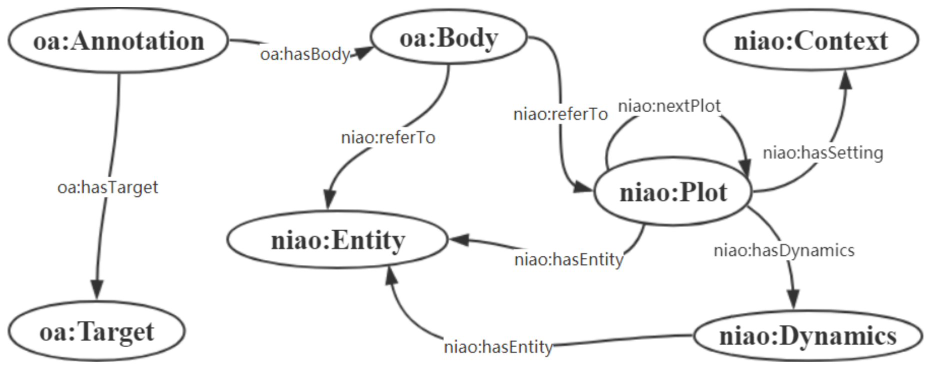

Fig. 2. Narrative Image Annotation Ontology

Plot In NIAO, a *plot* is referred to a *Body* of an *Annotation* in OAC. Due to spatial-temporal information in art image are vague, so we add spatial information into *Plot* rather than make them independent like other Event models do. So *Plot* contains temporal semantic relations in themselves. The temporal semantic relations between plots can be expressed through the following object properties. The *nextPlot* and *prevPlot* are widely used in temporal relations between plots, and the rest temporal relations are referenced to Allens [1] temporal relations of time, which are more strict with the beginning and ending of plot time. In plot annotating task, we can choose these properties to express more precise relations based on actual scene. These properties are *overlaps, overlappedby, meets, meets, starts, startedby, during, contains, finishes, finishedby, equals.*

We need to note that temporal relations of plots in narrative images are implied in images and they are not necessarily to occur in order according to the direction of space of image. Such as Figure 1, these story plots develop from both sides of the image to the middle. And this can be seen as some kinds of painting techniques of arts.

There also exists spatial relations between plots. Comparing with temporal relations, spatial relations between plots in narrative images are more abstract too in culture heritage. Spatial relations are referred to locations or places that the plot happens at. In culture heritage paintings, it is very difficult to compare geographical place relations of plots. By contrast, taking geographical place as a kind of entity is more appropriate to reflect spatial information and semantic relations in narrative images in labeling task. So we just treat spatial information like CIDOC-CRM [5] does in Figure 3.

Entity In a *Plot*, there should be some entities making this plot happen. In our model, we use *crm:Entity* for reusability. Entity includes *character/person* usually, and *animals*, *plants*, and other related objects. These objects are modeled using *crm:Biological_Object* or *crm:Man_Made_Object* in our model. *Entity* especially character can be assigned a *Role*, such as *King*, *Actor*, *Recipient* etc. We use *sem:Role* and *sem:Type* [18] to represent entity's role and its type, and properties like *isRoleOf* and *hasRole* from AgentRole ODP [15] are also introduced into our model to express the relationships

[15] See http://ontologydesignpatterns.org/wiki/Submissions:AgentRole

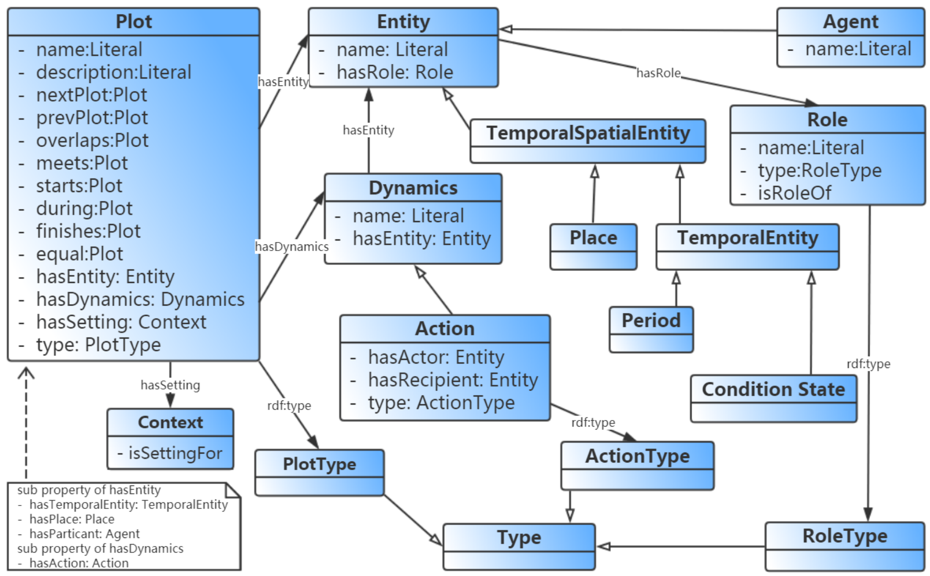

Fig. 3. UML Diagram about the Core Classes and Properties defined in NIAO

between entity and role. Note that, the domain of property *hasRole* is *Entity* rather than *Person* for the reason that some other objects also have roles to play in plots.

In art images, location or place in them are usually characterized by mountain, river, palace and other objects, rather than a specific geographical location, such as a specific province, street or a specific latitude and longitude. It is the same to time information in images, because it is difficult to express time through image way, such as *Dynasty*, *Month* that *Plot* involved in. External text resources are needed to refer when we annotate time information in images. In image content, time information is usually like *Morning* or *Spring* and other abstract information, which can be identified by certain entities and drawing techniques usually. For example, if there is a sun in image then it is daytime, if it is sunset then the time information is about evening etc, and they can be regarded as entities in images. Time information could be inferred from these entities.

Therefore, we use *TemporalSpatialEntity* as an *Entity* type to represent time and space information in narrative images to satisfy image annotation task requirements. Under this entity type, *Place* and *TemporalEntity* are assigned as subclasses, each of them is equal to *crm:Place* and *crm:TemporalEntity*. In this way, vague time information or time with uncertainty and inaccuracy like *Morning*, *Summer*, *Weekend* and so on can be represented easily. At the same time, precise time information like date, minute can be expressed by *crm:Event* which is subclass of *crm:Period*.

Note that time in reality is continuous, but in a narrative images time is discrete. For example, one plot might happen in the morning, another plot is likely to happen in another year's afternoon. Time elements cannot reflect the development sequence between plots, that is the reason why we represent temporal relations among plots by plot itself rather than by time.

Dynamics Dynamics is referred to Rossana Damiano's vocabularies [4] in our model as shown in Figure 3. *Action* is a type of *Dynamics* and *Dynamics* has different types namely *DynamicsType*. Image is a static object, and dynamic elements in image are better represented by *Action*. *Action* has two object properties, *hasActor* and *hasRecipient*, each of them represents the actor and recipient of the *Action*.

Context *Context* provides extra extension ability of this model, and it contains environment, background information, other textual descriptions information of plot, which should normally be aligned to a separate information object patterns or vocabularies for specification. It can help to understand plot and image in deep from *Context*. *Context* is similar to *InformationObject* class in EventCore ODP[16] and *Situation* class in Situation ODP[17]. We use *Context* to express these semantic information in our model.

There may be differences in actual labeling task, according to different partitioning granularity of plot in narrative images. A plot is labeled or marked in an image region, and different regions can be overlapped, which can be interpreted as that different plots share the same content elements on image. Although overlapping relations between different area of image regions can be accurately computed by pixels of regions, but we represent this overlapping relations through OAC *Target* in a more intuitive and convenient manner.

The spatial relations properties between different regions of image include non-overlapping (*no_overlaps*), complete-overlaps (*complete_overlaps*), contains, partial-overlaps (*partial_overlaps*). In this four overlapping relations, *no_overlaps* and *partial_overlaps* properties are common, this is also a common skill of simplicity in art of painting.

4 Use Case and Discussion

4.1 Annotation Tool and Process

An tool for Narrative Image Annotation (NIA) has been developed embedding with NIAO. The web UI of this tool is shown in Figure 4. All properties from NIAO are embedded into this tool as columns, and we differentiate two different properties namely image level metadata like *author*, *annotator*, *shot_time* of this image, and region level properties, like *hasPlot*,*hasAction* and so on from NIAO. Users can also add new columns in the end of column of table to extend this model in their annotating task. Most of the time, annotators only need to type a row number under some columns, such as *nextPlot*. Users can also upload their own annotation data into NIA for annotating work next time.

During annotating, annotators can upload some images and related texts (optional) into NIA, and draw rectangle, circle, ellipse and polygon shapes on this image. Then user annotate the marked region in lower table by filling correct values. Each annotation row represents an image region, under *type* column, user can select *Plot* or *Entity* or their subclasses as content value when a region is marked. The actions value of column $hasActor^{-}$ and $hasRecipient^{-}$ are usually filled by verb or verb phrase. This tool can help user choose NOUN or VERB conveniently from imported sentences as *Entity* or *Action* values in annotation table filling process (left part in Figure 4). Automatic image object recognition or annotation as a function can be integrated into NIA in the future (there is a button in the up-right corner of Figure 4 for this purpose).

[16] See `http://ontologydesignpatterns.org/wiki/Submissions:EventCore`
[17] See `http://ontologydesignpatterns.org/wiki/Submissions:Situation`

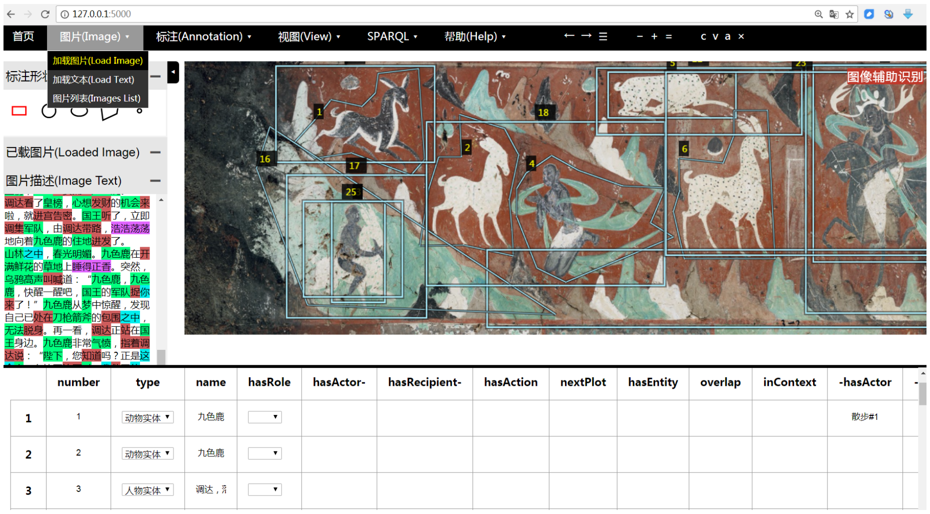

Fig. 4. Narrative Image Annotation Tools UI

4.2 Annotating Result and its Publishing

Annotation data including marked regions' pixel values can be downloaded as JSON,CSV and RDF data from NIA. Each row from annotation table is assigned a URI and has its type. The pixels data are transformed into region data according to SVG vocabularies[18] and make an extension to OAC. There is a rdf fragment of circle annotation region for example.

```
<http://niao.whu.edu.cn/anno2> a oa:Annotation ;
    oa:hasBody <http://niao.whu.edu.cn/body1> ;
    oa:hasTarget [
        oa:hasSource <http://niao.whu.edu.cn/thing1> ;
        oa:hasSelector [
            a oa:SvgSelector ;
            dcterms:conformsTo <https://www.w3.org/TR/SVG11/> ;
            cx 120;  cy 150;  r 10]] .
<http://niao.whu.edu.cn/body1> niao:referTo <http://niao.whu.edu.cn/plot1>;
```

Figure 5 shows a visual annotation result of three plots in Figure 1, because of space limitation, Figure 5 does not shows complete annotation result. Annotation data is stored in a Graph Data Base and some interesting SPARQL sentences like Figure 6 could be queried, and these table results can also be rendered in a storytelling way like lower part in Figure 6 in which each plot is marked to corresponding region with sequence number:

4.3 Discussion

We know that machine learning techniques are fairly common to be used for automatic or semi-automatic generation of annotations in the field of computer vision, but in this

[18] https://www.w3.org/TR/SVG11/shapes.html

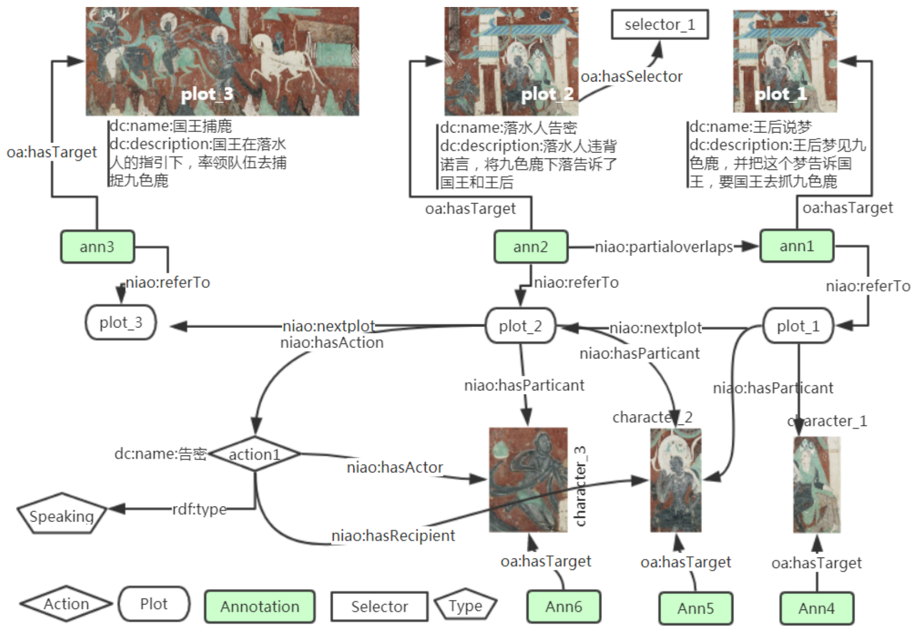

Fig. 5. Annotation Result Using NIAO and NIA

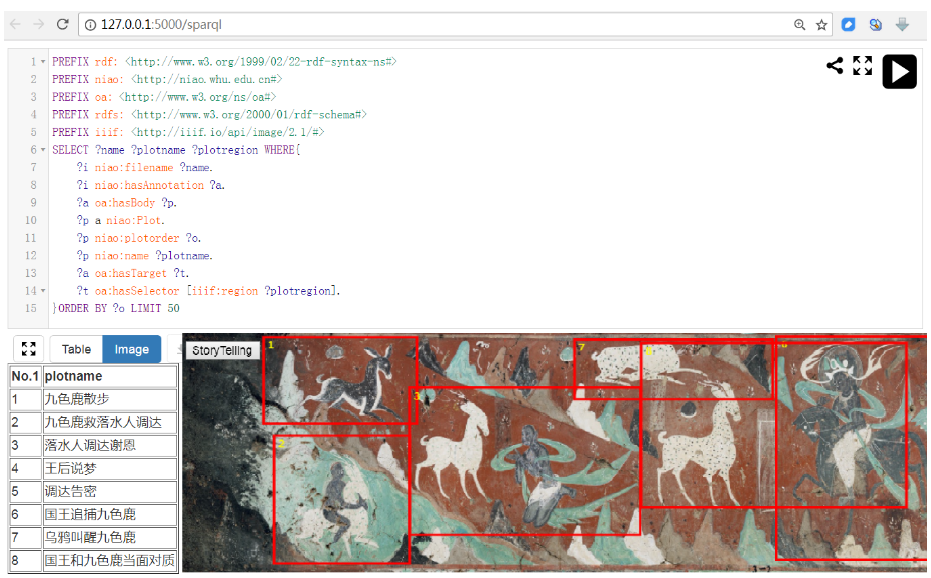

Fig. 6. Sparql Query for Finding all Plots in Figure 1

paper, NIA is designed to be done by manual. There are already some researches in the current study on common digital image dataset, but few studies have been done on images in the field of cultural heritage due to lack of deep labeled information of images. Our tool can help user annotate digital images. Note that, narrative images or paintings themselves with original authors who painted them have their own intended understanding of paintings, and modern users perceived understanding to images are also vary, so the granularity of plot's segmentation in narrative images is different according to different annotators.

We have collected many event models in semantic web field in Section 3, and it comes out that there is no best model but only suitable one according to specific task and application. We could also see that lots of studies about detection, representation, and exploitation of events in the semantic web. In these works, event models built or adopted to formalize event data are different to some degree due to different domain and application, including different richness and granularity of original data, different requirements from different users, different task and goals, etc. All of these lead to different event types and difference between these event models. However, commonness does exist among these models, events or narratives in them are located in space, occur over some time, have a prescribed type, and have participants, etc. This gives scholars some hints that when we confront with detection, representation, exploitation of events or other related stuff, these dimensions should be considered. NIAO is also could be seen as an event model designed for narrative image annotation especially in the field of cultural heritage. According to those CQs mentioned in Section 1, NIAO could answer there questions, and it also fits NIA well and applied in narrative images exploration successfully.

5 Conclusion and Future Work

In this paper, we have designed a narrative image annotation model and annotation tool in the field of cultural heritage. The model and tool were applied in narrative image annotation task, and annotation dataset could be published as linked data and based on this dataset visual sparql query results are also supported. The result shows that this model fits users' requirements and the annotation tool's functions very well to some extend.

There are still a lot of work to be done in the future. First of all, with a large number of cultural heritage images, we need to explore how to use computer vision technology to assist in identifying entities or narrative plots in images. The annotation data will be public available as rdf linked data, and we will also design some interfaces for future extensions. Some specific domain vocabularies can be imported through *Entity* class to support entities linking and other applications. Wordnet vocabulary can also be used in annotating process to help formalize *Action* term value for smart semantic searching. ICONClASS can also be used to make annotation data linked to other outside dataset. Other technical improvement such as text plot recognizing, further evaluation of annotation tool, image accessing in a standard manner by using IIIF[19] also need to be done in the future.

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[19] See `http://iiif.io/`

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