A Model of Derived Roles

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Abstract. Roles are important concepts in order to consider practical instance managements. Although roles have been discussed by many researchers, there remains some room to investigate to clarify ontological characteristics of them. This paper focuses on roles which are dependent on the future or past event/process, such as candidate, departing passenger, murderer, and product etc. In order to deal with such kinds of roles based on an ontological theory of roles, we introduce a model of derived roles with its temporal model. It could provide a computational model to represent temporal characteristics of roles.

Keywords: ontological engineering, role, derived roles, temporal model

1   Introduction

It is very important for ontology building to distinguish clearly among concepts in the real world based on their characteristics. Dependences of things are one of key characteristics which we should pay attention when we develop ontologies. So, how to deal with "dependency" is one of the key technologies in ontology building. Among them roles such as *customer*, *president*, *pedestrians*, etc. are dependent on other entities. A company can be a *customer* of another company while being a *supplier* to others. Proper treatment of roles is crucial to building a good ontology. This is why the topic of roles has been investigated extensively in several areas of ontology engineering[1-6], biomedical[7], database model[8], software engineering[9], and agent systems[10] etc. In practical point of view, in order to consider identity of some entities for instance management, it is important to understand characteristics of roles[11].

Although roles have been discussed by many researchers, there remains some room to investigate to clarify ontological characteristics of them. For examples, is *murderer* a role? Some answer no. A reason would be because one cannot stop being a *murderer* once he/she has started to play it. Another would be "it is odd to say "he plays a murderer" if not in a drama". Although these reasons are reasonable to some extent, we need a convincing explanation of what *murderer* is ontologically. This paper focuses on roles which are dependent on the future or past event/process, such as *candidate*, *departing passenger*, *murderer*, and *product* etc. In order to deal with such kinds of roles based on an ontological theory of roles, we introduce a model of derived roles with its temporal model.

This paper is organized as follows. The next section overviews our model of roles discussed in [3] to provide readers with background of the discussion of a new model

of roles. In Section 3, we propose a new view of roles to distinguish **derived roles** from **original roles**. In Section 4, we ontologically analyze temporal issues of derived roles in the context of enumeration of kinds of roles. Finally, we present concluding remarks together with future work.

2   Overview of our role theory

The fundamental scheme of our roles at the instance level is the following (see the lower diagram in Figure 1.):

"In Osaka high school, John plays teacher role-1 and thereby becomes teacher-1"
This can be generalized to the class level (see the upper diagram in Fig.1):

*"In schools, there are **persons** who play **teacher roles** and thereby become **teachers**."*
By **play**, we mean that something "acts as", that is, it contingently acts as according to the role (role concept). By "**teacher**", we mean a class of dependent entities which roughly correspond to a person who is playing teacher role and which is often called a *qua individual* [2] or *relational tropes* [6]. Our theory introduces a couple of important concepts to enable finer distinctions among role-related concepts: *role concept*, *role holder*, *potential player* and *role-playing thing*.

By **context**, we mean a class of things that should be considered as a whole. Unitary entities and relations can be a context of its parts and participants, respectively. **Role concept** is defined as a concept which is played by some other entity within a context. So, it essentially depends on the context[4]. By **potential player**, we mean a class of entities which are able to play an instance of a role concept. In many cases, potential players are basic concepts (natural types). When an instance of potential player is playing an instance of a role concept, we call the instance a **role-playing thing**. In this example, we say a person can play an instance of a teacher role. In particular, John is actually playing a specific teacher role, *teacher role-1*. By doing so, he is associated with the instance *teacher-1*, an individual teacher **role holder**. A role-holder class is a class whose instances include, say, *teacher-1*. As such, it is neither a specialization of a potential player class (e.g., person) nor that of a role concept class (e.g., teacher role), but an abstraction of a composition of a role-playing thing and an instance of role concept, as is shown in Fig.1, which is the heart of our role model.

In this paper, although the term "role concept" is important, we use "role" to denote" role concept" for notational simplicity.
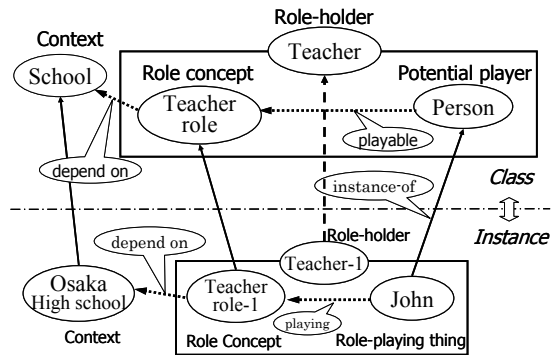

Fig. 1. Fundamental scheme of a role concept and a role holder.

3   Original and derived roles

3.1   Classification of role

The issue here is the fact that there are many kinds of roles other than what we usually see in the literature on roles such as *teacher*, *president*, *wife*, *patient*, etc. According to the types of the context on which roles are dependent, we can identify two kinds of roles such as those dependent on continuant and those on occurrent. Many of the popular roles including those mentioned above belong to the former. On the other hand, there are quite a few roles depending on processes or events. They include actor roles such as *driver* and *runner*, task roles such as *symptoms* and *fault hypothesis* played by states in the context of diagnostic tasks, functional roles such as *level-control valve* and *steering wheel* of a bike, artifact role such as *table role* which a box plays, etc. All these roles mentioned thus far are **ongoing**, by which we mean the context the role depends on is present when the role is being played. Surprisingly, at first glance, there seem to be quite a few roles whose contexts are not present when they are played. Typical examples include *murderer*, *culprit*, *witness*[1], *victim*, *product*, *residue*, etc[5]. However, as we see it below, those roles are not **original roles** but **derived roles** derived from the corresponding original roles. We have to be very careful not to be caught by language expression-based justification/understanding of roles. Roles should be understood as the original definition defined directly in the context.

Original and derived role holders are defined as follows:

Def. 1 Original role holder (ORH) =**def** *role holder defined as a participant of its depending occurrent or relation as its context or role holder defined as a part of an object as its context.*

Def. 2 Derived role holder (DRH) =**def** *non-original role holder which forms a role based on a content-oriented reference to corresponding original role holder (ORH), shares the same name with ORH but has different meaning (role) from ORH, and the time of playing of DRH differs from that of ORH.*

A typical example is *murderer* which means "a person who killed a person" in English and it seems to be a role holder with a historical property. Considering the role model discussed in section 2, however, we can find an original *murderer* role holder which means "a person who has just completed a killing action". Then, we can consider "a person who killed a person" as a derived role holder derived from the original role holder.

Linguistically, *examinee* means a person/student who works/studies hard to pass an (entrance) exam, so it seems to be a prospective role holder. However, it should be a derived role holder because it has no direct context of the taking exam as a process. Its original role holder should be "a person/student who is taking an (entrance) exam" defined in the context of an exam-taking process. The former role holder which has a prospective property should be understood as a derived one from the original one.

Another example suggesting a danger of relying on linguistic justification would be *(biological) child* in which people would ignore the difference between the instantaneous event of being born and its persisting existence after it. It is true that it is very

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[1]   This is not a person who testifies what his/her saw in a court but a person who saw the event.

special ontologically in the sense that the player (John) is born at the same time when the new entity as a *(biological) child* (role holder) of his parents is born. Concerning the above difference, however, *(biological) child* and *murderer* share the same characteristic, and hence *(biological) child* should be understood as a role holder defined at the very time of having been born. Both *child* and *murderer* carry the property after the appearance event.

We know the above explanation is rather informal. Although we deeply discusses on this topic in other paper[12], let us here summarize the above observation as follows: All original roles are ongoing. Roles which seem to be retrospective and/or prospective roles are derived roles derived from original roles. These are represented in the taxonomy of roles shown in Fig.2 which clear distinction between original and derived roles is made at the top-level.

Role
Original role (ongoing)
  non-participatory role (continuous)
    wife, patient, teacher, friend, etc.
  occurrent-dependent role
    process-dependent role (continuous)
      dynamic
        speaker/listener,runner,symptom, witness, examinee
      static
        baby/infant/adult, the sick
    event-dependent role (instantaneous)
      murderer,victim,residue,conclusion, mother,(biological) child, departing passenger
Derived role (non-ongoing)
  retrospective
    murderer as a person who had killed a person
  prospective
    examinee as a person who studies hard to pass an exam

Fig. 2. The taxonomy of roles.

4   Ontological analysis of a temporal aspect of derived roles

We built an ontological model of the temporal aspect of derived role holders as shown in Fig.3 to examine them in detail. In terms of the temporal model of derived role holders, it seems we can introduce a two-class classification into role holders, in which we call **prospective derived role holder** such as *examinee* as a person who studies hard to pass an exam and *departing passenger* and **retrospective derived role holder** such as *murderer* as a person who had killed a person, *victim* and *(biological) mother*. As will be discussed below, when we consider role holders derived from an occurrent- dependent role holder, any original role holder has three variants associated with it. In the following, in order to represent them systematically, we introduce three names: *derived role holder1* to *derived role holder3* as follows:

Derived role holders (denoted as **DRH**)
    *Derived role holder1 (denoted as **DRH_ev**): Retrospective or prospective reference to the player of an event-dependent role holder*
    *Derived role holder2 (denoted as **DRH_pr**): Retrospective or prospective reference to the player of a process-dependent role holder*
    *Derived role holder3 (denoted as **DRH_ag**) : Aggregation of derived role holders from an occurrent-dependent role holder*

In the following sections, we denote *derived role holder1* to *derived role holder3* as **DRH_ev**, **DRH_pr** and **DRH_ag** respectively, and we denote the roles of these derived role holders as **DR_ev**, **DR_pr** and **DR_ag**. For example, by *murderer-*
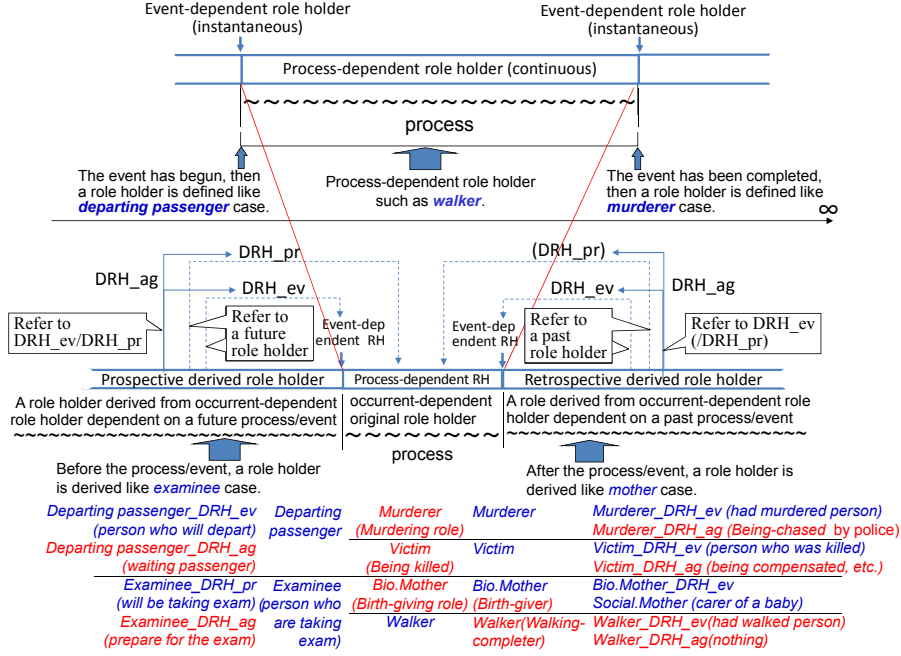
Event-dependent role holder
(instantaneous)

Event-dependent role holder
(instantaneous)

Process-dependent role holder (continuous)

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process

Process-dependent role holder
such as *walker*.

The event has begun, then
a role holder is defined like
departing passenger case.

The event has been completed,
then a role holder is defined like
murderer case.

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DRH_pr

(DRH_pr)

DRH_ag

DRH_ev

DRH_ev

DRH_ag

| Refer to DRH_ev/DRH_pr | Refer to a future role holder | Event-dependent RH | Event-dependent RH | Refer to a past role holder | Refer to DRH_ev (/DRH_pr) |

Prospective derived role holder

Process-dependent RH

Retrospective derived role holder

A role holder derived from occurrent-dependent role holder dependent on a future process/event

occurrent-dependent original role holder

A role derived from occurrent-dependent role holder dependent on a past process/event

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process

Before the process/event, a role holder
is derived like *examinee* case.

After the process/event, a role holder is
derived like *mother* case.

Departing passenger_DRH_ev
(person who will depart)

Departing passenger_DRH_ag
(waiting passenger)

Examinee_DRH_pr
(will be taking exam)

Examinee_DRH_ag
(prepare for the exam)

Departing passenger

Examinee (person who are taking exam)

Murderer
(Murdering role)

Victim
(Being killed)

Bio.Mother
(Birth-giving role)

Walker

Murderer

Victim

Bio.Mother
(Birth-giver)

Walker(Walking-completer)

Murderer_DRH_ev (had murdered person)
Murderer_DRH_ag (Being-chased by police)

Victim_DRH_ev (person who was killed)
Victim_DRH_ag (being compensated, etc.)

Bio.Mother_DRH_ev
Social.Mother (carer of a baby)

Walker_DRH_ev(had walked person)
Walker_DRH_ag(nothing)

Fig. 3. An ontological model of occurrent-dependent roles

DRH_ev and *murderer-DR_ev* we mean *murderer as a derived role holder1 (DRH_ev)* and *its role,* respectively.

4.1 Retrospective derived role holder

By retrospective derived role holders, we mean role holders which are derived from an original role holder defined dependently on past processes/events. By past, we mean before the playing time. For example, a *murderer-DRH_ev* as a person who killed a person is derived from an original role holder, *murderer,* dependent on a past killing event in which its player participated. To consider how retrospective derived role holders are dependent on past processes/events, we define the above three kinds of derived role holders for each original occurrent-dependent role holder. For simplicity, we take up the case of actor role in the following discussion.

In the case of *walker*, *walker as a process-dependent role holder* corresponds to normal *walker* which denotes "a person who is an actor of walking process", and *walker as an event-dependent role holder* denotes "a person who has just completed a walking action" which is odd in reality. Event-dependent role is the role defined as being born at the very moment of the completion of an event and hence it cannot have any chance to work during the event, though it is played only at that instance of time. Similarly, a *murderer as event-dependent role holder* appears only at the very moment of the completion of the killing event. How can we refer to the *murderer* after the murder event, then? Here, we introduce *DRH_ev* to represent the reference to an *event-dependent role holder*. *DRH_ev* is a role holder defined as "a person who had completed an action" to refer to the person and we call it "**content-oriented refer-**

ence[2]". That is, *DRH_ev* is derived from an action completer role holder (*event-dependent role holder*). For example, when people say "He is a murderer", they do not mean a *murderer*, which is realized at only the very end of the killng event, but a person who had committed the killing event. *Murderer-DRH_ev* can be understood as a "name" to specify the referent in a content-oriented way. When we refer to an entity through *DRH_ev*, it is not necessary that a player of the referent role is present in reality at the time of reference, since the reference to the player of *the original role holder* which the *DRH_ev* specifies is always successful independently of the existence of the player who must have existed when the *original role* was played.

On the other hand, a *murderer* is expected to play a *target role* to be caught by the police and/or to be punished by justice. But, it is not a *murderer-DRH_ev* since a *murderer-DRH_ev* is a referent to a participant of a past event while the target of police must be a real person who killed someone. That is, we can consider the role as another kind of *murderer* role which is expected to be played by the player of *murder*. In order to represent this kind of role, we introduce *DRH_ag*. In the murderer case, *murderer-DRH_ag* is defined as aggregation of "*a person who is being chased by police*" or "*a person who is being punished by justice*", etc.

The problem, however, is that they are not what "murderer" literally means. Those role holders are derived from the *murder* and their roles are expected to be played by the person who plays *murderer role*. Therefore, these roles are not only "*being chased by police"-role* or "*being punished by justice"-role* but also "*being chased as a murderer by police"-role* or "*being punished as a murderer by justice"-role*. *Murderer-DR_ag* should be defined as an aggregation of these roles which are expected to be played as *murderer* in reality.

Here, we have to note that a *DRH_ag* does not have to have real players in some cases. For example, a *victim* might be a person who was killed by a murderer. If we consider such a victim as a *DRH_ag*, the player of *victim-DRH_ag*, which is the person who was killed, does not exist in reality because he/she has been dead. Although most of the derived role holders such as "*a person who is being chased by police*" or *experience-teller* need a real player, target of action by others such as "*target of sympathy*" do not need real players if the target can be identified. In the case of *murderer-DRH_ag*, "*blameworthy target as a murderer"-role* could be played even if the murderer is dead, while "*being chased as a murderer by police"-role* needs a real player. It eventually depends on derived roles whether or not a real player is necessary to play the role.

Next, we introduce *DRH_pr*. Although *DRH_pr* is also a content-oriented reference related to a past event, it focuses on a different time point from *DRH_ev*. *DRH_pr* does not refer to *an event-dependent role holder*, but *a process-dependent role holder*. That is, *DRH_pr* is a reference to a role holder dependent on an ongoing process which is a constituent of the past event while *DRH_ev* is reference to a role holder dependent on a completion of the process/event. This is the difference between *DRH_ev* and *DRH_pr*. Note that both can be either retrospective or prospective references. For example, *DRH_pr* could be used as references to actors who are asked to explain how they performed the process in a situation where a *murderer* is accused of

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[2] The initial idea of "content-oriented reference" in this paper is also mentioned as "facons de parler" in P. 6 in the previous paper (but it is regarded as not a role but just a name) [5].

the process of how he/she killed a person, or an *Everest summiteer* talks about how he/she overcame his/her difficulties in the climbing process[5].

However, *murderer-DRH_pr* which means a person who was murdering does not make sense because "murder" is essentially an accomplishment action. Moreover, in general, *DRH_pr* is minor in the retrospective case since such a role holder is realized by using the original role holder in the past tense such as "*a walker was humming a song*". This is partly because when we retrospect past events, we tend to regard their results as more important than their process in many cases. For example, a *murderer* is blamed for the result of killing a person, and *Everest summiteer* is respected for the result of reaching the summit of Mt. Everest. Therefore, *DRH_pr* and *DRH_ag* for it do not make sense to define theoretically.

As discussed above, in theory, we can define all of derived role holders for each of occurrent-dependent roles. However, all kinds of retrospective roles do not make sense well. While *walker as a process-dependent role holder* makes sense, *walker as an event-dependent role holder* and *walker-DRH_ev, walker-DRH_pr, and walker-DRH_ag* do not. While *murderer as an event-dependent role holder, murderer-DRH_ev* and *murderer-DRH_ag* do, *murder as a process-dependent role holder* and *murderer-DRH_pr* do not. *Mother-DRH_ag* makes sense very well, since a mother is expected to take care of her new-born baby. This clear difference is derived from the difference of the nature of actions constituting the event or process, that is, from the difference between actions which are of continuous process-oriented type like *walk* and those which are of achievement-oriented type like *murder*.

4.2 Prospective derived role holder

By prospective derived role holders, we mean derived role holders which are defined dependently on future events. We can define three kinds of prospective derived role holders such as *DRH_ev*, *DRH_pr* and *DRH_ag* for each original occurrent-dependent role holder in the same way as retrospective role holders while directions to the depended process/event on the temporal axis are symmetrical (see Fig. 3).

In prospective role holders, an *event-dependent role holder* is defined at the very beginning of an event. For example, a *departing passenger* is defined dependently on a departure or travel event in the future. In the same way as *murderer*, *departing passenger role* is played only at the instant that the departure event begins. That is, *departing passenger-DRH_ev* represents reference to departing passenger as *an original event-dependent role holder*. Furthermore, we can define *departing passenger-DR_ag*, which is role expected to be played by the *departing passenger* such as "*waiting passenger*"-role, in the same way as retrospective roles. Although they make sense, *DRH_ev* and *DRH_ag* of *departing passenger* seem less meaningful than that of retrospective role holders such as *murderer-DRH_ev* and *murderer-DRH_ag*. This is caused by the point of time difference on which we focus to define these roles. After a completion of an event, we tend to consider its result to be more important than the process of completing the event. On the other hand, when we discuss about a future event, we consider that not only the beginning of the event but also the progress of the event are important. In order to investigate this tendency, we take an *examinee* as an example. An examination is an accomplishment type of event, so it fits better to talk about prospective roles than departure which finishes in a moment.

We can define an *examinee* as a prospective role holder which depends on the future examination. For a person who takes an exam, its progress is more important than its beginning. This suggests that we should define the *examinee* as not *DRH_ev* but *DRH_pr* which refers to the original process-dependent role holder depended on a future examination (taking an exam) process. *Examinee-DRH_pr* refers to the person who is going to take an examination and it is the prospective version of the content-oriented reference. The common meaning of the word examinee is a person who studies hard for preparation for an exam. Similarly to the murderer case, the actor role holder of such a derived role can be defined as *DRH_ag*, which is *examinee-DRH_ag*, to be played by the *examinee-DRH_pr*. Here, it is obvious that the purpose of the preparation is not to start to take an exam but to do his/her best through the whole process of the examination. This shows that *DRH_pr* is more important than *DRH_ev* in prospective derived role holders while *DRH_ev* is more important than *DRH_pr* in retrospective derived role holders. We suppose it is because most prospective roles are played to prepare for the future process on which they depend.

4.3   Discussion

In our co-authored previous paper [5], formal constraints of definitions of specific roles and some kinds of roles are discussed in a formal way. In particular, its main aim is to solve the famous counting problem. In the discussion of the kinds of roles, the initial idea of derived roles is discussed and then formalized as historical roles using an example of *the-climber-of-Everest* whose salient characteristic is that it lasts forever even after the death of him as well as possessing a historical property.

In this paper, we elaborate the ideas of "derived roles" based on "content-oriented reference" further and then propose a new theory of derived roles based not on a historical property but on a reference to (the player of) a past event. We found such kind of roles which seem to have a historical property should be decomposed into two types of the derived roles based on references, i.e., a reference to the player of an event-dependent role holder (*DR_ev*) and aggregation of roles based on such a reference (*DR_ag*). In addition the proposed model is symmetrical with respect to time as shown in Fig.2, which can cope with not only historical roles but also "future roles" mentioned in the footnote 16 in [5].

4.4   Computational model of derived role holder

Based on the above considerations, we built a computational model of derived role holders in our role model discussed in Section 2. Fig.4 shows an example of retrospective role holders represented by the extended role model. Although it is informal description, we can implement it using our ontology development tool Hozo and export in OWL format if a formal representation is needed.

An event-dependent role can be represented using the conventional model. The context for the event-dependent role is the completed event, and the relationship between them is represented by a usual depend-on link since the event exists at the time when the event-dependent role is defined. On the other hand, though the same event becomes the context for *DR_ev* and *DR_ag* as well, it is regarded as a past event when they are played. This is why relationships between the event and *DR_ev* and *DR_ag*

Fig. 4. An example of retrospective role represented by the computational model.

are represented by retrospectively-depend-on links. Relationships between a derived role holder and its original role holder imply the derived role is derived from its original role. Derived-from links represent that *DR_ev* and *DR_ag* are derived from the original event-dependent role.

DR_ev is defined as a subclass of a referent role. The referent role holder represents the role holder such as "something to which is referred by the role as name". In Fig.4, *murderer-DRH_ev* represents the referent for "the person who is referred to as murderer". The player of *DRH_ev* is its original event-dependent role holder because it has to be the same instance with the player of the original role holder. It is represented by a framework for compound role we discussed in [3].

DRH_ag is defined as a role holder whose player is *DRH_ev* as referent for the event-dependent role holder. As we discussed, *DR_ag* is an aggregation of a couple of sub-roles. By has-role-part links between *DR_ag* and these sub-roles, we mean the *DR_ag* has those sub-roles as its pats. We also identify *is-a* relation between *DR_ag* and those sub-roles. It looks strange at first glance. However, it is not so peculiar considering cases where both *is-a* and *part-of* relations hold between a pie and piece of pie and between finger composed of five fingers and a finger. In Fig.4, *has-role-part* links represent the *murderer-DR_ag* is defined as the aggregation of its parts such as "being chased as murderer by police"-role or "being punished as murderer by justice"-role, etc. Each part of the *murderer-DR_ag* is defined as the subclass of *murderer-DR_ag* and expected roles such as "being chased by police"-role or "being punished by justice"-role, etc. using multiple inheritance.

Though Fig.4 shows only *DRH_ev* and *DRH_ag* in this example, we can model also *DRH_pr* in the same way by replacing the event-dependent role holder with the process-dependent role holder. We can also define prospective roles using the same model with several minor changes. To put it concretely, the context for *DRH_ev* becomes the future starting event, and relationships between the future event and *DR_ev* and *DR_ag* are represented by *prospectively depend-on* link.

5   Concluding remarks

In this paper, we introduced a distinction between original and derived roles and a temporal aspect of them. Deriver roles derived from occurrent-dependent roles are classified into two kinds such as prospective role and retrospective role. Basically,

there is the symmetry between retrospective and prospective derived roles, and each of them has three variants such as *DRH_ev*, *DRH_pr* and *DRH_ag*. Then, we built a computational model to represent these roles based on our role model discussed in [3]. We believe this model could capture important characteristics of occurrent-dependent roles and it could contribute toward understanding temporal aspect of them.

Future work includes deeper investigation on derived roles and other kinds of roles. One of important issue is how to deal with derived roles which are derived from roles other than occurrent-dependent roles. What we precisely mean by "explicit role assignment", what is a vacant role, etc. are other topics to be discussed.

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