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Practical Considerations on Identity for Instance Management in Ontological Investigation

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Abstract. For knowledge representation based on ontology and its use, it is desirable to understand phenomena in the target world as precisely and deeply as possible. The ontology should reflect the understanding of them and provide a fundamental framework to manage the behavior of instances adequately. The management of instance model requires identity of things. Contrary to the common understanding, there are several kinds of identity according to the purpose of its use. This paper discusses how many kinds of identity exist and what kind of identity suits to what purpose. Based on the consideration result we suggest four kinds of identity and discuss what situation to be applied.

Keywords: Identity, Instance management, Roles, Ontology

1. Introduction

Ontology has been used as the basis of knowledge systems in various domains, and its utility is recognized more widely day by day. An ontology provides “an explicit specification of a conceptualization” [1] underlying any knowledge representation (an instance model), and it is one of the important roles to keep the consistency and reusability of knowledge by describing them based on the ontology. Many researchers study ontological theories intended to contribute to building a well-founded ontology. Especially, theory of roles is one of the critical topics. Roles have various characteristics such as anti-rigidity [2], dynamics [3], context dependency, and so on. We have been investigating these characteristics of roles and how to deal with them on computer systems as accurately as possible. As a result, we have developed an ontology development/use tool, named Hozo, based on fundamental consideration of roles [4].

In spite of the intensive work on theory of roles, however, there still remains some room for investigation of instance management problems such as the counting problem [5], appearance/disappearance of instances of roles, dynamic change of roles which players play, and so on. It is important to establish an ontological theory for instance management of roles so that we can capture their behavior and manage them in a sound manner.

Especially, identity of an instance of role concept and role holder has various characteristics [4], and we can observe several kinds of identity according to target tasks. This motivated us to investigate the issue of identity of roles and normal

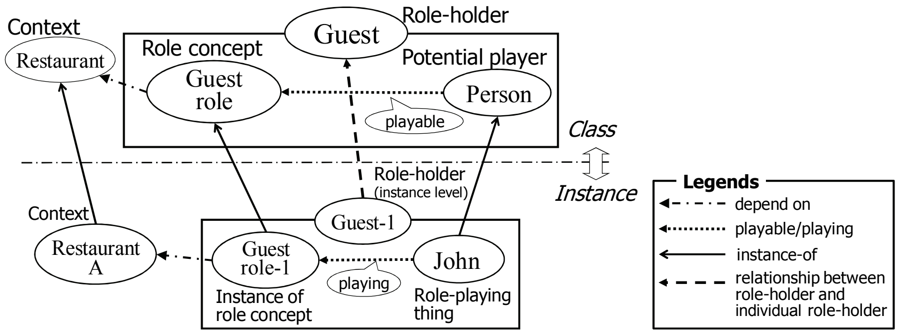

Fig.1 Fundamental scheme of role concept and a role holder.

types as well from practical point of view. We discuss what kinds of identity we need and try to enumerate its kinds so that we can study instance management. In addition, in developing a system based on ontology and Semantic Web technologies, the importance of identity problem, e.g. identity of resource on web, the same name problem, identity through linking and so on, is discussed [6, 7].

This paper discusses a property of identity to talk about instances, and introduces four kinds of identity that seem useful from practical point of view. The next section summarizes problems of identity in instance management and presents some motivating examples. Section 3 discusses classification of identity recognized generally. Section 4 discusses a nature of identity which is our subject in this paper, and introduces four kinds of identity. Section 5 discuses identity of role concept based on the four kinds of identity. Section 6 gives some discussion about applying those identities to instances of role concept and normal types. Related work is discussed in Section 7, followed by concluding remarks.

2. Motivating examples

Let us show our model of roles in Fig.1. We divided the conventional notion of "Role" into two kinds: role concept and role holder in our model. The fundamental scheme of our role model is the following:

> "In a context, there are potential players who can play role concepts and thereby become role holders" [4, 10].

For example, "In restaurants, there are persons who play guest roles and thereby become guests." (Fig.1). The link from Guest-1 to Guest is not completely same as instance-of relation because the individual role holder to be instantiated inherently requires first an instance of a potential player (e.g., person) class and of a role concept class (e.g., guest role). Identity of the role holder is composed by that of the role concept and that of the player. For example, identity of the guest role holder is determined according to the identity of guest role and that of person. Note here that our model assumes the existence of role concepts that are not played, we call them "unplayed roles" in this paper and they are understood as possessing identities.

Before presenting some motivating examples, we mention the identity discussed in philosophy.

Any P, P(X) = P(Y) ⇔ X and Y are identical

It is called numerical identity. Although it is philosophically very important and interesting to investigate what it means, it is not very practical for talking about identities of individuals, since it is useful only for saying that any thing is identical to itself and since every individual changes as time goes. In practice, it is often the case to talk about diachronic identity rather than synchronic identity. This suggests we would need other kinds of identity in everyday practice of ontological investigation. Consider the following examples:

(1) Imagine you are renewing your bike by changing its parts. How many parts or what parts can you change before you say "It is not my bike anymore!"?

(2) Assume you are replacing a part of a bike one by one to fix it, or you are removing skin of an orange to eat it. What do you answer when you are asked what bike you are fixing, or what skin you are removing? You will answer "I'm fixing ***this*** bike[1]" at any time or "I'm removing skin of ***this*** orange" at any time and "***this bike***" and "***this orange***" must denote "the same thing", respectively, independently of when you are asked. What identity do you use in such a case?

(3) When you have three four-sided figures, one figure is pressed to change its form from a square to a diamond. The thing is not square anymore, but you still have three four-sided figures. What identities do you use to say "this square has lost its identity" and "I have three four-sided figures independently of the change." Ontologically, counting needs no time, but it needs time in practice. Then what happens if one figure changes and looses its identity while you are counting the number of figures you have? The resulting number is influenced by the change or not? Is the change of the number influenced by what identity you use for counting?

(4) We consider a problem of counting the number of guests a restaurant served in a month. In the problem, there is no need to identify who are the guests. Rather, it is sufficient to count the number of guests role holders in the month independently of who came when. When we interpret the calculated number from the identity of guest role, the number coincides with the number of instances of guest roles played by persons within a month. What identity of guest roles do we use in such a case? When you, as an owner of the restaurant, want to serve more nicely to frequent guests than others, you need to count number of guests in the month paying attention who played guest role to count how many time particular person came to your restaurant. What identity do you use in such a case?

(5) How about the number of parliament members? The number of Japanese lower house is 480. When a member resigned, then a vacancy appears. It is interpreted that an *unplayed* parliament member role appears. What identity does the unplayed role individual has? Is it the 138th position of the member role, or the 41st roles? Of course, not. There is no difference between all the 480 unplayed roles. But, we should be able to count how many unplayed role individuals exists in the lower house.

(6) In a school, a Math teacher resigns, and then an unplayed teacher role appears in the school. What happens if the same person comes back to the school and starts to play a Math teacher role after a year. Does the person play the same teacher role individual or another teacher role individual?

(7) We assume John, an associate professor of Osaka University gets promoted to full professor. If we model this promotion process as that John directly plays the associate

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1 By "this", we do not mean the referent but mean the one the person is manipulating.

professor role and he changes the role to play, he has to stop being a member of Osaka University at the instance of he stops to be an associate professor. To avoid such a difficulty, a new mechanism is necessary for guaranteeing the continuity of his being a member of Osaka University while he changes roles to play.
(8) When the Prime Minister of Japan changes from Aso to Hatoyama, we can regard that they play the same role as the head of the Japanese Government. However, we also can recognize they play different roles (e.g. 92th and 93th Prime Ministers). What kind of role instances do we need to explain this?

It is apparent that the numerical identity is useful for neither of the above examples. At first glance, numerical identity would seem to be useful for the role of parliament members. This is because unless the constitution changes the role of parliament members, all parliament roles seem to be numerically identical. However, those 480 unplayed roles cannot be identical, if so, there would be only one member in the lower house. What is salient in the above examples is that there seem to be multiple kinds of notion of *identity.* When we count who came how many times to a restaurant, we needs to identify who is the person. But that identity should be weaker than numerical identity since the same person might gain weight at the next visit. On the other hand, the identity must be stronger than that used for just counting the number of things because counting needs no identification of what the counted objects are. The identity in the example (1) is similar to the one in (2), but is different in that your bike cannot change by replacing all the parts with new ones until becoming a totally different bike from your original one. So, we can investigate how far we can change its parts before it becomes not your bike. A very weak identity is found in (2) in which whatever change is made, "*this bike/orange*" keeps its identity until the very maximum change, since you must be able to fix the bike you are given first and to eat the orange you are given first.

Example (3) has a very special notion of identity. Some researchers say "a thing loses its identity when it changes the class it belongs to due to its change" It is correct in most of the cases where we are interested in each thing in usual tasks. Such a notion of identity is not at the instance level but at the class level. That is, such an identity could be called "class-level identity" since it loses its essential property for belonging to the original class, while it is not certain if it also loses another (instance-level) identity or not. On the other hand, if we are only counting four-sided figures, the change of a figure from a square to a diamond has no influence. This strongly suggests that we need a special identity for counting which is weaker than class-level identity. On the basis of the observation thus far, we investigate the kind of identity and characteristics of them.

3. Classification of Identity

In this section, we summarize kinds of identity which are discussed in general. There are two kinds of identity of an instance; identity which discusses the sameness of the class (*Class identity which we called class-level identity in the above*) it belongs to and identity which discusses the sameness of instances (*Instance identity*).

Instance identity is further divided into the following two kinds:

- ***Synchronic identity***
- ***Diachronic identity***

The main target we consider in this paper includes synchronic identity and diachronic identity of individuals(instances) which are discussed in the following sections.

3.1 Class Identity vs. Instance Identity

Class identity and instance identity are discussed based on essential properties of concepts as follows:

Essential property: A property which determines the identity of its instances. In other words, it loses its identity[2] when the property changes.

For example, we can consider that essential property of bikes, which is an artifact, is "aggregates of the parts such as two wheels, and functions such as to carry a person by human power", and so on. From an engineering viewpoint, we permit arbitrariness to capture an essential property of a concept unlike the philosophy. Class identity and instance identities are defined using *Essential property* as follows:

Class identity of a thing: Identity for discussing the sameness of the class the thing belongs to. It is also defined as belongingness of things to the class which is determined by essential property.

For example, we assume the necessary condition (essential property) of being a bike as having two wheels. When a wheel is removed, the bike loses its class identity and thereby it stops to be an instance of bike. This identity can apply to the example of four-sided figures discussed in section 2.

Instance identity: Identity for discussing the sameness of instances. The conventional numerical identity is a kind of instance identity.

For example, when a saddle and a wheel of Taro's bike (i.e. an instance of bike) have been replaced with new ones, it is discussed using the instance identity whether the bike after the replacement is the same or not for Taro, that is, if Taro is happy to accept it is his bike or not. Although difference between these two types of identity has not attracted much attention to date, it is practically important. In fact, while replacing the engine of a Porsche with one of a Beatle cannot change class identity, it changes its instance identity.

3.2 Synchronic and Diachronic Identities

There is another set of identities such as synchronic identity and diachronic identity.

Synchronic identity: Identity which represents the fact that two individuals are the same thing at a given time.

For example, let us assume a question that "Are they the same one hour from 10:00 to 11:00 and one hour from 11:00 to 12:00?" The answer is "Although they are different as a time interval, they are ***the same*** as a quantity of time." The *synchronic identity* means ***the same*** in the answer. The identity corresponds to the sameness in another

[2] This should usually read "class identity".

example such as "the evening star and the morning star are ***the same*** star, that is, Venus, though they have different names".

Diachronic identity: Identity which discusses the sameness of instances at two time points.

For example, the diachronic identity is used to discuss the sameness of individuals in the cases such as "Whether Taro, an instance of person, at present is the same person with the person five minutes ago or not", "Whether an instance of bike and the bike some of whose parts are replaced are the same or not" and so on.

4 Consideration on Instance Identity

In this section, we discuss the sameness of instances and kinds of identity of normal types to prepare for investigation on that of roles in next section. The target of our consideration is instance identity, that is, we focus on the sameness of instances in the scope of the same class identity. We consider kinds of identity according to their strength by which, we mean how strictly the sameness of instances is judged. For example, we assume a case where a bolt of an instance of bike is replaced with another one. In this case, there could be two positions:

1. Strictly speaking, the bike whose bolt is replaced becomes a different bike from the bike before the replacement.
2. The bike has been the same bike before and after the replacement of a bolt because the change is negligible.

While the identity of the former is stronger than one of the latter, it is needed some more discussions about the latter case to judge whether the change is negligible or not when you are renewing your bike. We can also find a weaker identity. In the example of counting the number of guests at a restaurant, identity used for just counting the number of them is weaker than that used for counting who came how many times. The above example suggests that there would be several kinds of identity according to their strength. In this paper, we introduce four kinds of identity according to its strength and features of each identity in the following sections. Three of them are diachronic identity and the last one is synchronic identity. The four kinds of identity can be applicable to all instances.

4.1 Identity for Exactness

Identity for exactness (denoted as ***Iex*** in the following) that corresponds to numerical identity: Identity which means the exact sameness.

For example, we consider an instance of bike. When a bolt of the bike is replaced, ***Iex*** tells us the bike changes because the bike has a different bolt after the replacement. Therefore, the bike whose bolt is replaced is different from the previous bike before the replacement in the meaning of ***Iex*** (Fig.2).

The meaning of the exact sameness in the definition of ***Iex*** implies the change of instance as time goes by. For example, because an instance of bike rusts as time goes it changes without replacements of parts in terms of *Iex*. In the actual world, because all individuals can be regarded they undergo change at least in molecular level as time

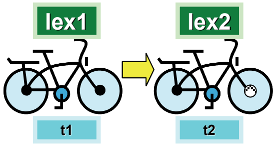

Fig.2 ***Iex*** applied for bike.

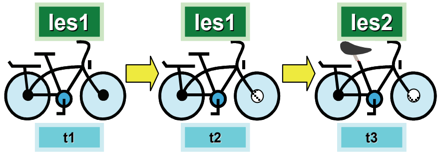

Fig.3 ***Ies*** applied for bike.

goes. In practice, however, we often recognize that an instance of bike is the same even if a bolt of it is replaced. We can find similar recognition when we suppose instances of person. For example, John at present can be recognized as the same person with him five minutes ago while he is different in terms of ***Iex*** at the two time points. It is necessary to define identity which is weaker than Identity for exactness to deal with such sameness adequately.

4.2 Identity for Essentiality

Identity for essentiality (denoted as ***Ies*** in the following): Identity which is defined by essential property

For example, we assume essential property of John's bike as a comfortable saddle which he has used for ten years. We consider ***Ies1*** which the bike has (Fig.3, t1). When a part of the bike is replaced with a new part, the bike has kept ***Ies1*** unless the essential property (essential to John), it is the saddle in this example, is replaced. Therefore, the bike is treated as the same bike to John even if a bolt is exchanged because the essential property does not change (t2). However, when the saddle is replaced with other one, ***Ies1*** changes to ***Ies2*** because the essential property of the bike to John is changed (t3).

4.3 Identity for Counting

In a task of counting numbers of instances, we do not consider the details of each instance discussed in terms of ***Iex*** and ***Ies*** if following two conditions are satisfied: (1) we can recognize whether instances are the target to count or not, (2) we can distinguish each from others, and (3) we can avoid duplicate counting. Because the existence and the number of target entity are theoretically already fixed when a counting task is started, identity which is used for the counting task is synchronic identity independent of time.

Identity for counting (denoted as ***Ico*** in the followings):

Identity which argues about the number of instances (Synchronic identity) satisfying the above three conditions.

For example, when we count the number of bikes in Fig.4, we can recognize that there are five bikes in terms of $\boldsymbol{Ico}_{bike}$ ***1~5*** which is associated with each bike. If we want to count the number of mountain bike in those five, we should count only the number of ***Ico*** of instance which is belong to mountain bike class.We can also use ***Ico***

Fig.4 ***Ico*** applied for counting bikes.

for comparing only the number of instances at two different time points because ***Ico*** is identity representing the number of instances. However, ***Ico*** cannot discuss the sameness of instances at two time points because it is synchronic identity.

4.4 Identity for Replacement

Now, we assume a case where a counting as a real-world task which needs non-zero time to accomplish. If some parts of the target instance of counting are replaced during the counting task, we would fail to count them correctly. For example, we assume there are three bikes (A~C) and the situation that the two wheels of bike A was replaced during counting them. We also assume the essential property of these bikes as two wheels. Because ***Ico*** cannot discuss whether the bike changes its identity after replacement of parts or not, we try to use ***Ies*** for the counting task here (Fig.5). At first bike A~C have ***Ies1~3,*** respectively. If the two wheels of bike A are removed after we have counted bike A and B, ***Ies1*** disappears because the essential property of bike A disappears during (t1, t2). And when new two wheels are installed to bike A, bike A has new ***Ies*** (e.g. ***Ies4***) because new essential property of bike A is generated at t3. Then, we will count bike which have ***Ies3*** and ***Ies4***, bike C and bike A whose wheels are replaced, because we have not counted instances which have these identities yet. As a result, the number of bikes is four while actually there are only three bikes. This example shows that parts replacement of the instance can cause that we might fail to count the number of instances correctly in practice.

When we assume the parts replacement in the above example, we can consider bike A at t2 as "a bike during parts replacement". This consideration suggest we need another identity which does not change during parts replacement. We now introduce the fourth identity for replacement to solve such a problem.

Identity for replacement (denoted as ***Ire*** in the following):

Identity which an instance of the whole continues to be itself without becoming another thing *while* whose parts are being replaced independently of their kinds and number of the replaced parts.

For example, we consider the same situation as the example discussed in Fig.5. Here, we suppose bike A~C has ***Ire1 - 3*** before the counting task (Fig.6). Even if the two wheels of bike A are removed after we have counted bike A and B, bike A has kept the sameness in terms of ***Ire***. Then, we count only instance having ***Ire3*** after counting A and B, and as a result we can count the number of three bikes successfully. In this way, we can achieve a correct counting using ***Ire*** in the instance model in which the parts replacement can cause inappropriate counting using ***Ies*** .***Ire*** also can handle that bike A continues to be the same instance during the parts replacement.

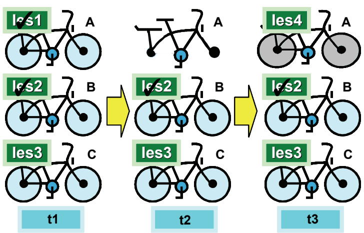

Fig.5 ***Ies*** applied for counting bikes.

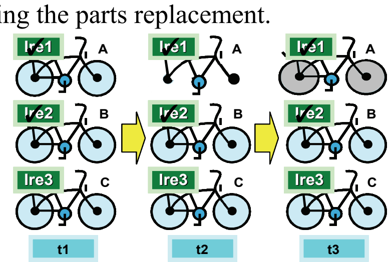

Fig.6 ***Ire*** applied for bike (count for bikes).

5. Identity of Role Concept

5.1 Identities of Constituent role and Post role

In order to cope with the continuity of membership while changing roles to play as shown in example (7) discussed in section 2, we introduce two new concepts such as ***constituent role*** and ***post role*** by dividing role concept into two parts: one is the player's participation in the context and the other is what kinds of post the player is required to fulfill. We call the former *constituent role* and the latter *post role*. In addition, the post role is played not by the player directly but by constituent role-holder. See details [10]

In the case of promotion, not John but John as a Osaka university constituent role holder is playing the associate professor post role, so when he gets promoted, he can stop to play the associate professor post role while keeping the continuity of his participation in the Osaka University. In the case where he resigned, on the other hand, the constituent role individual disappears. If he returns to Osaka University in a few years later, he will play another Osaka university constituent role different from the one he played a few years before. This is consistent with the reality in handling personnel ID in companies where no personnel ID is reused and for each employment a new ID is assigned to the employee independently of he/she had been an employee of this company or not.

Fig.7 shows a revised model of roles shown in Fig.1 after introduction of ***constituent role*** and ***post role.*** The modeling methodology is the same as that used for modeling Japanese prime minister role must be played by Japanese citizen, that is, the methodology used for modeling compound roles [4]. While we are designing formal representation of this model using OWL based on our previous work [8], it beyond the scope of this article. Note, however, that the methodology is not the issue. What we claim here is that constituent role must exist in any role model, and any role (post role) must be played by constituent role holder.

5.2 Instances of constituent role and post role

Post role should correspond to a kind of specification of properties and functions of what a player is expected to play and is almost equivalent to what is claimed by Guarino and Massolo in [2, 3], that is, there is only one post role for each role concept in a context. Therefore, we do not need to discuss ***Ico*** for it, while, similarly to the basic type, ***Iex***, ***Ies*** and ***Ire*** should be investigated for post roles to see how it changes diachronically.

Contrary to the fact that basic types necessarily change in any second because of natural degradation of its material, however, post role does not change in such a sense because it is immaterial. Note here that it is true unless the context changes its definition. For example, a school can change the role of teacher when its policy changes, which would suggest that post role does not have ***Iex***.

The creation of constituent role is done synchronized with the event of player's participation in the context. So, when the participation is finished, then it disappears.

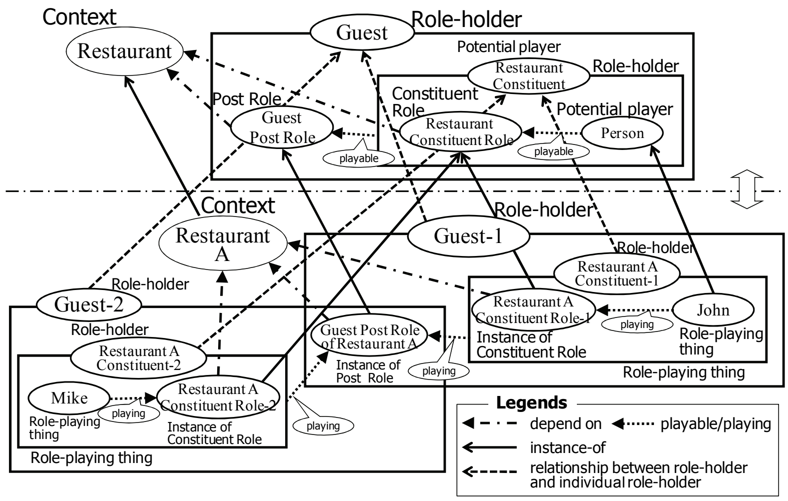

Fig.7 Revised model of roles.

While the player is participating in the context, it keeps playing the constituent role. Therefore, we can consider the essential property of each constituent role is determined by the event of any player's participation in the context. That is, we can discuss its identity using ***Ies*** based on that essential property. Multiple constituent roles for a context have different identities in terms of ***Ies***.

We can distinguish between instances of constituent role by the time when it is created (in what order it is created) in terms of ***Ies***, while we can use ***Ico*** if there is no need to discuss in what order they are created like in the case of parliament constituent roles. In the case where fixed number of roles are predetermined, like teachers of a school and parliament members, instances of constituent roles are created in advance by that number and exist in unplayed states. When vacancies appear by resignation of members, then same numbers of constituent roles should be created. On the other hand, in the case of no predetermined quota, like guests of a restaurant, they are created at the same time of new players' participation.

Let us see the example shown in Fig.7 in which there exists one *Guest Post Role of Restaurant A* as an instance of *Guest Post Role*. When John participates in the restaurant, an instance of *Restaurant A Constituent Role* as an instance of *Restaurant Constituent Role* is created[3]. John plays the constituent role and becomes *Restaurant A Constituent-1 Role-holder*. Then, John as *Restaurant A Constituent-1 Role-holder* plays *Guest Post Role of Restaurant A* and becomes *Guest-1 Role-holder*. *Restaurant A Constituent Role-1* disappears when John finished his dinner, and hence both *Restaurant A Constituent-1 Role-holder* and *Guest-1 Role-holder disappear*. Note here that *Guest Post Role of Restaurant A* is shared by multiple constituent roles to form different role holders because there is only one *Guest Post Role of Restaurant A*.

From the diagram shown in Fig. 7, it seems that five individuals such as *Restaurant A Constituent roles-1*, its player (John), *Restaurant A Constituent-1 Role-*

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[3] When we discuss another role such as chef role at the same context, constituent role is divided to into multiple roles such as restaurant guest constituent role and restaurant staff constituent role.

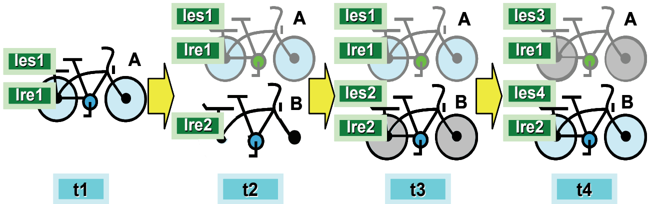

Fig.8 ***Ies*** and ***Ire*** applied for bike.

holder, *Guest Post Role of Restaurant A* and are participating in determining the identity of *Guest-1 Role-holder*. However, things are not that complicated. Because identity of role-holder is synthesized by role concept and its player, the goal is realized by the recursive application of this mechanism as follows: identity of constituent role-holder is determined by those of constituent role and its player, and then identity of post role-holder is determined by those of the post role and the constituent role-holder. In terms of identity introduced here can explain the examples shown in (4) through (8) as is discussed in section 5.

6. Discussion

This section discusses some examples to demonstrate what kind of problems we can deal with using these four kinds of identity which we introduced in the previous section. We discuss counting problem in next section, then we explain the examples of identities of roles discussed in section 2.

6.1. Counting Problem

The first is counting problems for the guest management in a restaurant discussed in section 2 and counting the number of river flows, the second is a more complicated problem of the parts replacement of bikes.

When we count only the total number of guests of a restaurant in a month, we can use weak identity, *identity for counting **(Ico)***, which can discuss only the number of guests. On the other hand, it is necessary to identify the individual guest using stronger identity, *Identity for essentiality* (***Ies***) of person, when we want to know how many times each guest comes. We explain this example in detail using identities of roles later. In the case of river flows for example, we cannot use ***Ies*** for counting the number of the flow of the water in the river because it cannot identify particular water of the river itself. We can count the number of river flow only if we use ***Ico***. These examples show, a kind of identity to apply is different according to whether we want to deal with particular property of the instance or only the number of instances.

Next, we consider a complicated problem of parts replacement of bikes. We here assume the essential property of the bikes as a two wheels, and apply ***Ies(Ies1)*** and ***Ire(Ire1)*** to the instance of bike A at t1 (**Fig.8**). When we replaced all parts of the bike A except the two wheels of it (t2), ***Ies1*** and ***Ire1*** of this bike are maintained. At the same time (t2), another ***Ire (Ire2)*** is generated when we are going to make another bike B using the parts which we removed from bike A. And another ***Ies (Ies2)*** is generated when new two wheels are installed to bike B (t3). Then, when we exchanged the two wheels of bike A and the ones of bike B each other, ***Ies1*** and ***Ies2*** are changed to ***Ies3*** and ***Ies4*** respectively (t4). In this example, the bikes at t3 and them at t4 are regarded as different bikes because of difference of ***Ies***, while bike A and B have kept same Ire, ***Ire1*** and ***Ire2*** respectively, because ***Ire1*** and ***Ire2*** are maintained regardless of parts replacement. In this way, we can deal with such complicated change of instances in each time points appropriately by applying ***Ies*** and ***Ire*** to the parts replacement.

6.2. Instance Identities of Roles

6.2.1. Guests at a restaurant (e.g. example (4) discussed in section 2)

When we count the number of guests of a restaurant in a month, we can count the number of instances of restaurant constituent role-holders which play guest post role of the restaurant while it is not necessary to identify particular players (persons) who play the constituent roles. If we need to know in what order each guest comes because an owner of the restaurant wants to give a special souvenir to the 1000th guest, we should use ***Ies*** of the restaurant constituent roles, which can discuss in what order they are created and their role-holders play the guest post role. If we want to count only total number of guests, we can use weak identity, ***Ico***, which can discuss only the number of the restaurant constituent roles.

Next, we consider services for guests. Only one instance of guest post role can exist at a restaurant and all players of guest role holders (restaurant constituent role holders) at the restaurant play the same post role. It implies that all guests are served the same service at the restaurant.

On the other hand, when you want to serve special menu to frequent guests who comes to the restaurant more than 3 times a month, you need to define sub classes of guest post role such as “guest post role for person who comes not more than 3 times a month” and “guest post role for person who comes more than 3 times a month”. In such a case, we need to know how many times each person comes and plays the guest post role, using ***Ies*** of person.

Note, when the same person comes to the restaurant twice, the same guest post role is played by him/her while different restaurant constituent roles are created and played each time. Therefore, guest role-holder at first time and that at second time are not identical. In this way, it is properly managed that guest role-holders are different from one another because their players (restaurant constituent role-holders) are different even if players of restaurant constituent roles, persons who come to the restaurant, are identical and they play the same guest post role.

6.2.2. parliament members (e.g. example (5) discussed in section 2)

At Japanese lower house, only one instance of parliament member post role exists and it is played by all parliament constituent role-holders. Parliament constituent roles are created by the quota number, that is 480, and exist in unplayed state before particular persons play them. Because there is no need to discuss in what order they are created or what number of parliament constituent role, such as the 138th constituent role, or the 41st constituent role, we can use ***Ico*** for them. When the house has dissolved, all of parliament constituent roles disappear and 480 new parliament constituent roles for next period are created. Then, period of the parliament, which is a non essential attribute of parliament member post role, is renewed, e.g. from 79th to 80th, without losing the identity of parliament member post role in term of ***Ies***. This enables us to properly represent the facts that the current parliament members of Japanese lower house is the 80th and that the member A who has recently elected by the election to fill a vacancy is the XYZth member in its whole history using ***Ies*** of parliament constituent role.

6.2.3. Math teacher (e.g. example (6) discussed in section 2)
When a Math teacher resigns in a school, the teachers' Math teacher post role remains same unless the policy of the school changes education to modify the role of teachers, while his/her school constituent role disappears. If the same person returns to the school and starts to play the Math teacher role again in a few years later, he/she plays the same Math teacher post role while he/she plays a school constituent role different from the one he/she played a few years before. Therefore, his/her Math teacher role-holder and the one a few years before are different in terms of *Ies*.

6.2.4. Japanese Prime Minister (e.g. example (8) discussed in section 2)
When Japanese Prime Minister changes, Japanese Prime Minister post role keeps same identity as the head of the Japanese Government while identity of Japanese Prime Minister role-holder changes because its constituent role changes. Even if the same person becomes Japanese Prime Minister continuously two periods, its constituent role also changes because he/she resigns at once and then is reappointed. The period of Japanese Prime Minister is represented as non essential attribute of Japanese Prime Minister post role like parliament members, and its value is renewed synchronized with the change of its player. Unlike parliament members, however, the value of the period corresponds to in what order the instance of Japanese Prime Minister constituent role is created because of its predetermined quota is only one.

7. Related work

In philosophy, two interpretations of "sameness" are discussed. The one is "qualitatively same" which means attributes of entities are same. The other is "numerically same". The former corresponds to *identity for essentiality*, and the latter corresponds to *exact sameness*. Graeme S. Cumming et.al discusses metamodel to define changing nature of complex systems. They refer to philosophical problem of parts replacement, called Theseus' ship, and discuss a metamodel based on this problem with engineering handling it [11]. The replacement metamodel does not support continuous identity. The identity corresponds to *identity for essentiality*. However, it seems their metamodel does not support *identity for replacement*.

Secondly, we summarize studies of identity in the point of view of engineering. Guarino applied identity to class recognition and proposed ontology construction methodology based on "identity criterion". He established a principle "a class can have only one identity criterion" [2]. Although all classes do not have identity criterions, it is useful for class recognition because we may think that "object" has identity criterion. Identity which used in the methodology is class identity described in 3.1. However, it is difficult to solve the parts replacement problem discussed in Section 4 by "identity criterion". Compared with them, we have classified instance identity in this paper and can handle the problem adequately according to kinds of identity.

In object-oriented modeling some researchers discuss identity which role concept has. [12]. Kristensen defines identity in object-oriented modeling as "An object and its role have the same identity". Furthermore, Alan Colman expanded this definition to "Roles have an organizational identity that is independent from their players even though the role and player constitute a unity within the organization" [13]. We can agree to the definition of Colman, because role concept is defined depending on context and independent of the identity of its player. However, they do not discuss enough about handling of diachronic identity of instances of role concepts such as generation/continuation/extinction of identity of the instance of the role concept depending on the existence of its player.

As discussed in the above, identity has been discussed in the field of philosophy, ontology engineering, and object-oriented modeling. Nevertheless, we do not know someone count up and discuss kinds of identity which is necessary for discussion of identity. That is, they cannot treat properly all of motivated examples discussed in section 2 because they do not support the 4 kinds of identity we proposed.

In semantic web technology some researchers discusses how identify resources on web. Presutti pointed out five distinct issues concerning identification of resources on the Web and has proposed IRE (identity of resources and entities on the Web) model to solve them. IRE is an ontology built on top of DOLCE+ and its extensions [6]. Halpin discusses identifying non-Web accessible entity and has proposed identity which is defined through relationships given on the Web as links [7]. These approaches are lower-level aspect of identity to represent identity practically on computer systems. They are very informative when we design implementation of our theory of identity.

8. Conclusion and future work

In this paper, we have discussed the sameness of instances at two time points and the property of identity on counting instances. As a result, we have identified four kinds of identity and suggested what task to be applied to them through some examples. These considerations provide fundamental theory to discuss identity and contribute theoretically to instance management on computer system based on ontology. For example, we could use the theory as a reference model when we design how a system should treat identify of instances, i.e. to identify whether some instances which have same id in different time point are same thing or not. As future work, we plan to in-depth develop a theoretical framework for management of identity based on the consideration. Furthermore, we plan to implement the framework in Hozo, an ontology building tool developed by us [14].

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