A Property Driven Approach towards Describing Semantics of REA Entities

Presented at The 2nd International REA Technology Workshop 2006, Santorini

Mette Jaquet
Software Development Group
IT-University of Copenhagen
mjaquet@itu.dk

June 25th, 2006

Abstract

The Resource Event Agent (REA) ontology as it has been presented so far does not explicitly describe the semantics of economic events. The lack of well-defined semantics for REA entities requires implementation experts to perform subsequent analysis of specific solutions based on models created by business experts, thereby leading to individual interpretations and decreased reusability, adaptability and evolvability of solutions. This paper presents a hypothesis that the lack of well-defined semantics for events is closely related to the lack of descriptions of properties of resources, and that choosing properties of resources as the starting point for REA modeling guidelines, can improve flexibility, adaptability and evolvability of both models and implementations of REA based systems. Using such techniques to enhance REA models could improve the consistency of models as well as shorten the path from business model to operational implementation of enterprise systems, and improve the possibilities of reusing domain knowledge of specialized semantics in different business areas.

Introduction

It has been a quarter of a decade since the REA model was first presented by William E. McCarthy as a powerful and innovative approach to modeling ERP systems. In the early descriptions of the REA model [McC79], [McC82] it was tailored to fit the context of accounting requirements in a single retail enterprise, and the extended REA ontology presented by McCarthy and Geerts in 1999/2000 [GM00] is still strongly influenced by that scope. If the context is extended to represent more than one enterprise, i.e. in when modeling Business to Business transactions from a global perspective or Supply Chain Management scenarios like Vendor Managed Inventory, this enterprise specific or view-dependent version of the model is not appropriate. Another extension to the context of the original REA model is to look not just at retail enterprises, but enterprises in general, including manufacturing enterprises.

As mentioned above the REA ontology [GM00] extends the original model with transformation events but they are not adequately described, and in examples of REA models they are rarely included and often inconsistently used.

The scope of the REA model has also changed with regards to the levels of enterprise functioning it describes. The entities of the original REA model belong mainly in the *Operational Level* covering day-to-day tasks of i.e. accountants, and the addition of transformations enables modeling of production operations, that are also part of the operational Level. However the Commitments and Agreements of the extended REA model, might take the form of i.e. production plans or budgets and allow the scope to include elements of the *Tactic Level* that involves short-term planning. The *Strategic Level* involving long term planning is beyond the scope of the REA model, and no attempt will be made to include it. Changing the scope from merely registering occurring events after they have happened, to including planned events have an effect on the model and its implementation, as it introduces a change from operating on known data to estimated data.

A consequence of adding transformations and resource planning to the scope is the increased importance of including temporal and spatial dimensions when modeling. When registering resource changing events that have already occurred they are less important, but when planning transformations all the necessary resources have to be available at the exact same time and place.

The first part of this paper aims at providing a better understanding of the semantics of transfers and transformations, including the differences between them and ways to classify and describe them. The second part of this paper presents a property driven approach to creating and implementing REA-based business models. The ideas are at a very preliminary stage and the feasibility of the approach has not yet been determined. However as the intention with this workshop is to discuss new ideas and ongoing work, we have taken the opportunity to include it as an interesting alternative to traditional datamodeling approaches. The REA model will not be described in detail here, as all the topics of the workshop evolve around the REA model, and readers are expected to be familiar with the REA ontology. For readers not familiar with the REA model [GM00] gives a good introduction.

Semantics of Economic Events in the REA Model

This section presents an attempt to provide more details of the ontological definitions of events, their semantics and the constraints that apply to their combinations.

Basic Event Types

The extended REA ontology [GM00]with basic entities and relations as shown in figure 1 defines *transfers* and *transformations* as the two basic event types. Furthermore it distinguishes between *inflow* and *outflow* events, and states three axioms that constrain their *stock-flow* relations to Resources and their *participation* relations to Agents. These definitions are stated as if they relate to both types of events in the same manner, but a closer examination shows that there are some fundamental differences between the two event types, and that it might not be possible to state the axioms in a manner that fits both. This section gives an overview of the characteristics of economic events.

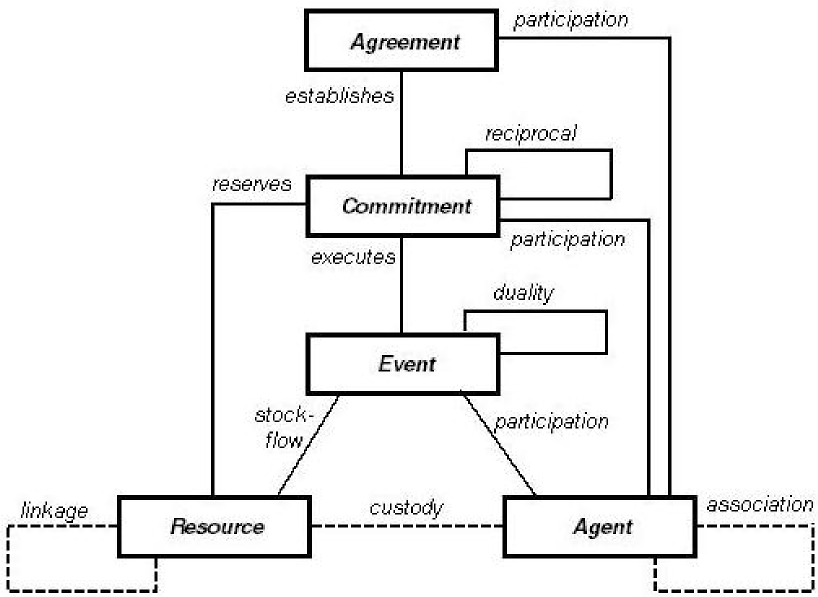

Figure 1: Entities and relations of the basic REA model

What is a transfer ?

According to the ontology [GM00] a transfer creates value through *market transaction with outside parties* and the two stock-flow relations associated are *give* (outflow) and *take* (inflow). In this version of the ontology agents are seen as either *inside* agents or *outside* agents. The common interpretation of these terms are as *internal* or *external* with regards to the enterprise in focus (which is itself an upper level agent composed by other agents i.e. departments and employees). Transfers typically take place between agents from different enterprises and have one internal agent and one external agent participating. But sometimes transfers within the boundaries of an enterprise take place. In this case the ontology's description of the terms *inside* and *outside* are to be interpreted in the sense *providing* or *receiving*. This non-symmetry of using sometimes one definition and sometimes the other leads to confusion when creating and interpreting models, and it causes problems if model evolution leads to changes like i.e. outsourcing parts of an enterprises activities. In this case some outside agents (in the sense "receiving") become inside agents (in the sense "internal") and vice versa. In this paper we will use the neutral terms "receiver" and "provider" as suggested in [Jaq03].

Another issue to consider is what is transferred when a transfer event occurs. Typically *ownership* of a resource will be transferred. If the scope of the REA ontology is within a single enterprise there is an implicit ownership relation to all resources modeled. If a resource is transferred to an external agent it disappears from the view of the model. There is however an explicit *custody* relation that can be interpreted as showing what agent has the rights and physical possession of a resource to transfer or transform it. If the scope of the ontology is enterprises in general a more detailed definition of transfers will be required. In general a transfer may be of one or more **rights** or **responsibilities**. Examples may be *rights of use* and *responsibility of maintenance* for rentals, *liability* as with insurance responsibilities during i.e. transportations. Music and other types of entertainment are usually sold with rights of use but limited rights of copying etc. Unless an agreement states otherwise transfer of ownership means transfer of all associated rights and responsibilities, but it is also possible to trade only some rights to a resource in an exchange.

What is a transformation ?

The REA ontology states that transformations are ”exchanges” that *create value through changes in form or substance* and consist of events that *produce* something (inflow) paired with dual events that *use* and/or *consume* something (outflow). When defining the terms use as *”using up resources in a way that cause them to disappear or leaves their form unrecognizable”* and consume as *”in making use of a resource in a way that leaves the original form discernible”* Black & Black from 1929 [BB29] p.30 is cited. The text referenced does not specify these exact terms and the common way to interpret them is the other way around. When using the Merriam-Webster Online Dictionary (www.m-w.com) consume is listed as synonymous with ”to do away with completely” and use is synonymous with ”the act or practice of employing something”. In this paper the terms are therefore used in the sense that consuming a resource is form-changing or destroying, while using a resource preserves form and identity.

Changing ”form or substance” is not the only way in which the value of economic resources can be changed by transformation. In [BB29] creating value through transformations is described as increasing the ”want-satisfying power” of resources and thereby their value in a sales situation. Three ways of altering the ”want-satisfying power” are mentioned in [BB29] p. 27. One is indeed changes in **form or substance** as the REA ontology mentions. But also changes in **placement or location** as well as changes in **time** are mentioned. As an example of how changes in the placement affect the value of resources can be cited *”A commodity which is in Madagascar when all the people who want it are in Europe has no want-satisfying power unless it can be transported to Europe”*. Transportation is thereby also a type of transformation that changes the spatial placement and value of a resource - without changing its form or substance. The effect of time on the value of a resource is illustrated by the fact that the value of a crop being harvested decreases rapidly, if it cannot be sold before it rots. Likewise the value of good wine can increase with time and Christmas decorations have significantly higher want-satisfying power in December than in June. Age and location as mentioned here are two examples of properties of a resource that can be changed to increase or decrease the value of the resource. But many other properties can be changed to affect the value of an item. I.e. a broken bicycle can be fixed, a recycled bottle can be cleaned, and an employee can be educated to give his or her services a higher value and so forth. So stock-flow relations called move, store, educate, clean and so on would all make just as much sense as use and consume. They would all indicate a change in some property of a resource as well as the value of the resource. Most of these changes will be changes of an identifiable physical property, but i.e. education can be seen as a non-physical value increasing transformation.

The only transformation event causing inflow is the *produce* event that identifies the result(s) of a transformation. The basic subtypes of transformations causing outflow could be stated as:

- **Use** of an economic resource, preserving form and identity. Black & Black call these types of resources ”fixed”.
- **Consumption** of an economic resource destroys it completely or changes its form or structure in a way that leaves it unrecognizable. Black & Black call these types of resources ”circulating”.
- **Transportation** modifies the location of a resource.
- **Storage** of a resource does not necessarily change the form of the resource in any way, but its value is changed due to the time. Christmas decorations are an example. Some resources may also have properties that can be changed by age.
- **Modification** of some specific property of a resource. I.e. *Repairing* a broken bicycle, *Painting* a car or *Educating* personnel in order to increase the value of the work they provide. These types of transformations change a single identifiable property of the resource.

Dualities of events

A key element of the REA model is the *duality* relation that shows which events form an exchange. It is not clearly stated in the ontology, but we make the assumption that only events of the same type (either transfers or transformations) can be connected by dualities. Following the discussion of the differences between the event types above, this seems reasonable as it would make no sense to exchange an altered relation (transfer) with a change of a physical property (transformation). The ontology used the term *Exchange* for dual events of both types. We prefer to introduce the term *Conversion* to distinguish the two from each other. This leaves Exchange as the term for dual transfer events and Conversion as the term for dual transformation events.

Another reason for introducing the Conversion is that there is a fundamental difference between the semantics of dualities connecting transfers and transformations. The inflow (produce) and outflow (use, consume, etc.) events in a Conversion are connected by dualities showing that these ”events” are *all parts of the same overall event or Conversion* as shown by the shaded area in the bread-baking example of figure 2. None of these events make sense to observe in isolation, they represent ”parts” of events taking place simultaneously and one cannot take place without the others. Some of the partial ”events” cause a decrement of resources and some cause an increment.

On the other hand dual transfer events may very well happen at different times and places and can be observed in isolation. In this case the incompleteness comes from the fact that a single event, i.e. a cash receipt (an increment of resources) represents only one side of a transfer. If a global perspective of the scenario modeled is assumed, the enterprise making the payment is included, and the other half of the transfer would be seen as cash disbursement event decrementing resources within that enterprise. The event recorded in one enterprise as a disbursement and in the other as a cash receipt is in fact the same event (shown by the shaded areas of figure 3, and in a global view they may be collapsed into a single ”transfer cash” event. If a duality across the boundaries of enterprises was shown the duality would

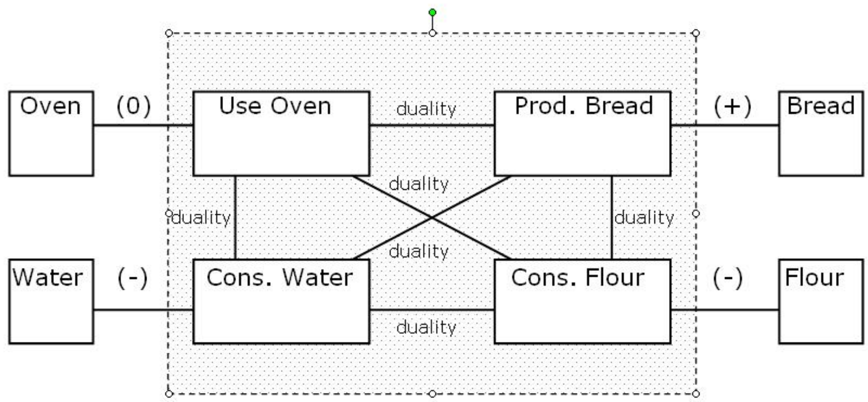

Figure 2: Dualities combining transformation events in a Conversion

be similar to the one used between transformations, connecting increments and decrements caused by the same event. However this is not how dualities are used between transfer events. They are used to show what the cash receipt was a payment of, i.e. the "Sell Item" event.

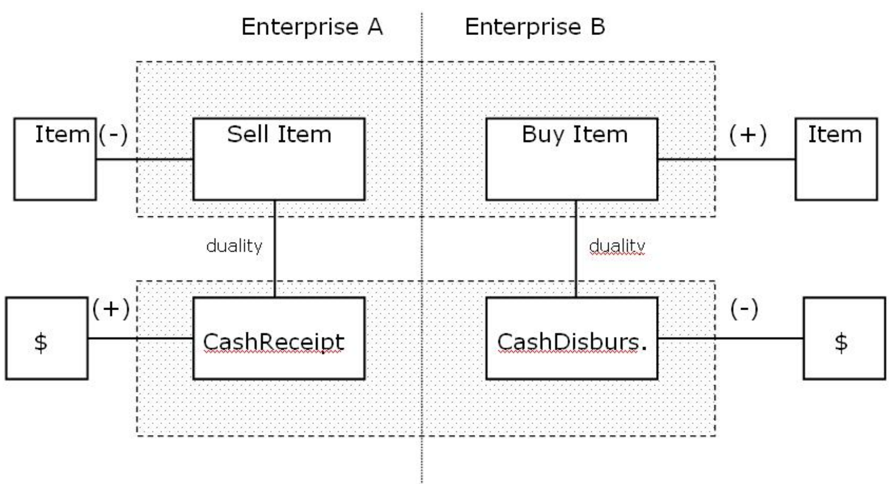

Figure 3: Dualities combining transfer events in an Exchange

The notion of *congruent* events is introduced in [GM00], describing multiple dual events that occur at the exact same space in place and time. An example of congruent transfer events might be a sale in a shop where both agents are present, and hand over the payment and the purchased goods at the same occasion. Transformations are not mentioned explicitly, but as argued above, they must be congruent by nature.

Axioms

The REA ontology [GM00] states three axioms to be observed for all model instances. They are defined as follows:

- **Axiom 1**: At least one inflow event and one outflow event exist for each economic resource; conversely inflow and outflow events must affect identifiable resources.
- **Axiom 2**: All events affecting an outflow must be eventually paired in duality relationships with events affecting an inflow and vice-versa.
- **Axiom 3**: Each exchange needs an instance of both the inside and outside subsets.

The inside and outside subsets mentioned in axiom 3 can be interpreted as internal vs. external agents with respect to the enterprise in focus.

The first axiom makes sense for both transfers and transformations. The second axiom is true for all transformations as resources cannot appear or change state out of the blue. Often a transformation involves at least three dual transformation events. I.e. production of goods by consumption of raw materials, and use of labor and machinery. For transfers the second axiom is often true, but as described by McCarthy in [2] for practical reasons single events with no dualities might be the best way to describe gains and losses and matched expenses like i.e. tax, heating and maintenance. The third axiom is not quite clear because of the different possible meanings of inside and outside. If inside/outside is meant in the sense internal/external it clearly only concerns transfers as transformations will only involve internal agents. If it is meant in the sense provider/receiver it might apply to both types of exchanges, with the addition that for transformations only, a single agent may be both the receiver and the provider.

It seems that the three axioms and the general descriptions of Exchanges and Events were made primarily with transfers in mind. The conclusion here is that there are differences between the two Event types that need to be observed, and that the nature of transformations is inadequately described by the ontology. A summarized overview is shown here:

Property	**Transfers**	**Transformations**
Are coupled by dualities in	Exchanges	Conversions
Are always	Across boundaries of agents	Within boundaries of an agent
Agents participating	Two, of competing economic interest	At least one
Dualities connect	Separate events	A congruent event
Temporal nature	Are instant	May have a duration
Change	Agent-Resource relations	Properties of a resource

Structured approaches to describing the REA entities

The analysis of semantic details of the REA ontology presented here, has so far been unstructured and intuitively guided by common reason. But there have been proposed more structured approaches to describing the semantic details of events. One example is in [GM02] where a mapping of the concepts of the REA ontology to Sowas ontological categories [Sow00] is proposed. A different type of approach to establishing structure and consistency of the model, could be to apply a variant of the classical data modeling principles using CRUD diagrams[1]. As the only actions within the scope of the REA model are economic events affecting the *state of resources*, resources are the primary REA entities subject to applying the CRUD principles on. The users management of agents, events etc. are necessary parts of a REA-based implementation, but not part of the value-flows modeled. Furthermore the ”R” (Read) from CRUD can be omitted as retrieval of information from the system is not modeled explicitly. That leaves us with investigating Creation, Deletion and Updates (modification) of resources as the essential events in a REA model. Creation and Deletion affect the existence of resources and correspond to the event types *produce* and *consume*. Modification on the other hand represents changes to the state of a resource and does not affect existence or identity. Whether transfer events affect existence or not, depends on the perspective the model is seen from. If a dependent (trading partner) view is assumed one may choose to model resources as being created/deleted when purchased or sold. If an independent (global) view is assumed the resources sold do not cease to exist, but merely change owners.

In [Hes06] a classification scheme is proposed, describing the effects of event types involved in a model for the SCM/VMI enterprise domain. It shows which of the resource properties as *ownership*, *liability*, *location* and *existence* are affected by the specific event types.

	changes ownership	changes liability	changes location	changes existence	stockflow direction
transfer	yes	no	no	no	bidirectional
consume	yes	yes	yes	yes	outgoing
produce	yes	yes	yes	yes	ingoing
load	no	yes	yes	no	outgoing
unload	no	yes	yes	no	ingoing

Table 1. Taxonomy for events and commitments

Figure 4: Table 1 of [Hes06]

The events listed form a general taxonomy of economic events in the given domain. When implementing specific solutions additional columns and rows may be added. This is one modeling approach where one event can affect several properties. A different approach would be to determine the semantics of events by using simple minimal events that each modify one property, and use these as small building blocks to put together more complex domain specific events like i.e. ”load” that changes both

[1]CRUD is an acronym for Create, Retrieve (or Read), Update and Delete (or Destroy). These are the actions that can be performed on data in a database and diagrams showing data vs. actions (C, R, U or D) can be used to describe what actions users are allowed to perform

location and liability. Note that events that change existence always affect all properties when shown this way.

Describing the same effects on resources and their properties using C(R)UD principles could be done as:

Transfer	U (ownership)
Consume	D
Produce	C
Load	U (liability, location)
Unload	U (liability, location)

This is an example of describing the semantics of effects of selected events from a specific restricted domain to a list of specific resource properties. The same principles of using the C(R)UD approach on relevant properties of resources, can be applied to any specific business case or domain. The following section gives an overview of how this can be done in a uniform manner based on classifications of the relations between the properties relevant to the model, and the ways they can be modified by events.

A Property Driven Approach to Applying the REA Ontology

Traditionally when the REA ontology has been applied to a business case as described in i.e. [DCH05], focus has been on which REA entities to model. What are the resources, agents and events present and necessary to record in that specific enterprise? Lets assume a different approach. As the aim is to model value flows within and to and from an enterprise, resources are a key entity, so lets start with them. Resources are affected by events. But the REA ontology doesn't say much about the semantics of events. What actually happens when an economic event occurs? The answer is that either a resource is added to or removed from the system, or some property of a resource is changed. If an item is sold the ownership is changed. If a car is painted the color and/or level of maintenance is changed, hereby changing its value. [GM99] states that ”*Value is defined as a deliverable portfolio of product or service attributes attractive to the firm's ultimate customers.*”. *So besides from exchanges, changes to the attributes or properties of resources is how the value within an enterprise can be increased.* When we use the term ”properties of a resource” it can be seen as synonymous with the terms ”attributes” or ”characteristics” often used in REA literature. We use the term in a slightly broader sense to call i.e. ownership a property, even if it may be thought of as a relationship rather than an attribute of a resource.

Various Types of Properties

Determining the characteristics or properties of a resource is a somewhat philosophical question, but in the context of REA models an answer to the question of whether or not to include a property, may be determined by considering whether or not changes to that property affect the value or availability of the resource. Specifying properties of resources is also closely related to determining the Resource Types of the Knowledge Level in a REA model using typifications and groupings as described in i.e.

[GM03]. The subject of typifications will not be addressed in detail in this paper, but the separation between static vs. dynamic and intrinsic vs. extrinsic properties described in the following seems essential in that discussion as well.

The REA ontology employs the differentiation between the *Operational Level* and the *Knowledge Level* as suggested by Martin Fowler in [Fow97]. At the *Operational Level* indentifiable instances of events, agent and resources are described and at *Knowledge Level* the notion of *Type Images* is used to describe the correlations between entities that exist, regardless of whether or not specific instances of the entities exist. In [GM00] p. 13 the example of a lion being a roaring member of the cat family is mentioned as an example of a relation that applies to all lions and continues to exist even if the lion race was to become extinct.

Based on this description it would seem reasonable to conceive the notion of typification in REA as a persistent segregation into static type hierarchies as known from i.e. the concept of inheritance in object oriented modelling. In this case a lion would be one subtype of a roaring cat animal, which again is a subtype of a cat animal, which is a subtype of a mammal and so forth, with each subtype inheriting the properties of its supertypes.

On the other hand additional examples from the REA domain are mentioned that don't fit this interpretation. One is the example of agent rankings where customer types (small, medium, big) and the experience of sales personnel (experienced, non-experienced) can be determined and matched. These typifications are not static, but can change dynamically during the lifetime of the agent entities. This seems to be rather like a way of specifying metadata that describe certain properties of the agents. One might say that ”small” ”medium” and ”big” are the possible values of a ”customertype” property of a Customer. Note also that these properties are exclusive - exactly one must be selected. Other similar properties as i.e ”locationtype” being ”domestic” or ”international” can be specified. This is also an indication that implementation by inheritance is not a good solution as this would lead to multiple inheritance.

Another example of typification from [GM00] is the distinction between the event types ”Specialty Store Sales”, ”Mail Order Sales”, and ”Internet Sales”. In this case the typification is indeed static due to the occurrent nature of events as opposed to agents that are continuant. This means that events have no dynamic properties and that inheritance could be used (although not necessarily recommended) for describing economic event types, as opposed to resource types and agent types.

Property Driven Modeling

The idea of using properties as a starting point for developing REA models is based on the central role of resources. If the essential issue of using REA to model enterprise systems, is to record the fundamental data of economic events, why not focus on what changes are made to the state of resources (the desired result of events) instead of i.e what processes currently take place in the enterprise? That way the structure of data recorded is not biased by the way it is currently used, and may possibly be useful in other areas of the enterprise functions.

The first steps of applying a property driven approach could be:

1. Identify relevant resources.
2. Identify their value-affecting properties.
3. Identify Buy/Produce and Sell/Consume events for all resources (fulfilling Axiom 1).
4. Identify relevant Modify events for all value-affecting dynamic properties.

Thus basing the selection (and naming) of events on the properties they modify, not the processes they take part in. Thereby the flexibility, adaptability and possibility of reusing data may be increased. Using the C(R)UD notation shown above to classify the events modeled and their effects gives a good overview of whether or not any events are missing.

The principles of identifying changes to properties may be a good tool when modeling solutions including transformations and conversions. In the case of a retail enterprise where transfers are dominant there would be not benefit of using this approach as steps 1 and 4 mentioned above are irrelevant.

Detaching Properties

When dealing with ontological engineering some challenges and decisions are often left open for interpretation as ”implementation issues”. It may however be beneficial to use the feedback obtained from implementing specific solutions to improve the ontologies as argued in i.e. [BS04]. How the attributes or properties of a resource are modeled and implemented have an impact on the flexibility and evolvability of solutions. During the lifetime of an enterprise system there may be changes to the way business is conducted, and how data is organized and connected determines how easy it is to adapt to changes. The ideas presented here are in many ways similar to those of adaptive programming and aspect-oriented programming.

When identifying properties, some are intrinsic to a resource and cannot be observed in isolation from the resource they describe, i.e. the serial number of a car. Others, like the tires a car is currently equipped with, are extrinsic. An interesting approach to take could be to detach properties from the resources they describe to the extent possible. This way the state of properties determining the value of a resource becomes a derivable value determined by the changes that have been made to that property. How to determine the value of the derived property depends on business logic associated with the events affecting the property. This way of registering state changes instead of maintaining a ”current state” value, is very similar to the central idea of the REA model being event-driven and recording i.e. changes affecting accounts and deriving the balances instead of maintaining a ”current balance” value.

If a company producing cars is taken as example, there could be a ”Mount Tires” event adding or changing the set of tires (a property) associated with a car. There might also be a ”Paint” event that adds/changes the color property, and a ”Anti-corrosion treatment” might update the date stating when it was last applied. If properties are detached as individual components related to resources, they and their related events can be reused for several different resources. I.e. a ”Paint” event that modifies a ”color” property and has information on quality, colorcode, and amount of paint to use, may be just as applicable to bicycles or dustbins. It also makes it possible to add new properties and their related events without changing existing resources. I.e. a car company may want to add a ”Has GPS” property to the features of a car. This is done easily by adding a ”Has GPS” property and a ”Mount

GPS" event, and allowing them to apply to relevant car types. Likewise if the car company decides to start a rental business an "Available for rent" property that depends on the most current of the two event types "Rented" and "Returned" may be added.

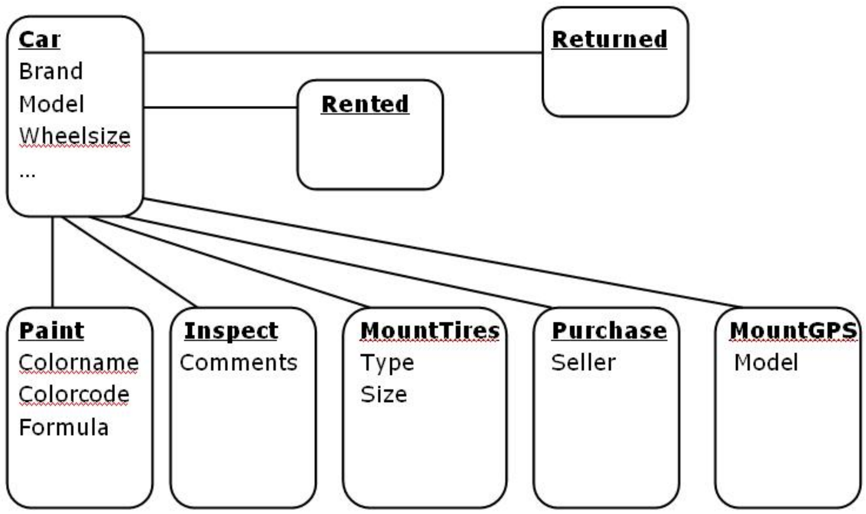

Figure 5: Different types of events affecting properties that may be associated with a car

Thus events may affect one or more properties, properties may depend on one or more events, and property-changing events may either accumulate or cancel previous changes (i.e. painting).

Conclusions

We have presented a non-formal but detailed description of the semantics of economic events in the REA model. In particular the difference between transfers and transformations and the dualities that connect them have been described. We have argued that the existing axioms of the REA ontology need to be modified and possibly extended in order to take the differences of the event types into account. A structured way of describing the effects of events on resource properties has been demonstrated using C(R)UD principles, and a property oriented way of approaching modeling conversions and implementing properties of resources has been outlined. The ideas presented are at a very preliminary stage and the possible benefits and drawbacks of using a property oriented approach are yet to be determined. But as shown the benefits may be seen in both the levels of modeling and implementation and the approach could possibly lead to increased flexibility, adaptability and consistency of solutions.

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