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Occurrence-centric E-commerce Applications Specification and Execution

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Introduction

We propose an occurrence-centric framework for formally specifying and executing e-commerce applications, motivated by a need to synchronize system models and system implementations. We describe what we mean by occurrences, and how participants in an occurrence can be specified, giving examples at each stage. In addition to regular workflow occurrences, we explain which types of occurrences can be used for creating ontologies and defining norms. We conclude with a discussion of how an occurrence-based system executes a specification.

Motivation

The objective of our approach is to allow business users to specify business policies directly, and allow systems to enact and enforce these policies, as well as to store, and eventually distribute, communicate, and collate, policies. Specifically, we wish to translate the policies directly to a formal logic, rather than into procedural program code as translation into procedural or object-oriented code breaks the synchronization between the system model and the system implementation, which we wish to preserve.

The approach we are adopting is to translate a requirements specification into a set of occurrences which name, classify, and describe the entities and concepts in the system, as well as the authorizations, obligations, and powers of users of the system, and of the system itself.

Occurrences

An occurrence is a particular time-delimited relationship between entities. Occurrences may be instantaneous (e.g. a momentary event or achievement), durative (a state, activity, or process), or discontinuous in time (see later). Occurrences relate participants in various roles; this can be represented as participant-occurrence-role triples[1]. For instance the factual occurrence of "Charles (identified as c1) submitting an application form" can be formally represented as in *Table 1* below:

Participant	Occurrence	Role
c1 (named 'Charles')	o1 (the submission occurrence)	r1 (submitter)
c2 (the application form)	o1	r2 (submitted)

Table 1: Representing "Charles submits an application form"

Here, o1 is the occurrence identifier for an occurrence of 'submitting', c1 and c2 are concept identifiers for Charles and the application form respectively, and r1 and r2 are role identifiers for the roles of submitting and being submitted respectively.

Occurrences may be simple or composite occurrences. For example, the simple occurrences 'Charles reading the insurance application form', 'Charles filling in his name and address, and the details of the items to be insured', and 'Charles submitting the insurance application form' may form part of the composite occurrence 'Charles applying for insurance'.

[1] These are motivated in part by Piercian trichotomy of firstness, secondness, and thirdness.

We choose to use deep roles[2], rather than merely thematic (semantic) roles, as the latter do not always uniquely identify participants in a given role in a commercial occurrence[3]. For example, in 'Charles buys bread from Walmart'[4], both Charles and Walmart can be construed to be in the 'agent' thematic role of the purchase occurrence, as Charles is doing the buying and Walmart is doing the selling. Using the deep roles 'buyer' and 'seller' allows us to avoid this vagueness. See for example, *Table 2* below.

Participant	Occurrence	Role
c2 (named 'John')	o2	r8 (buyer)
c3 (named 'Walmart')	o2	r9 (seller)
c4 (classified as a bread)	o2	r10 (bought)

Table 2: Representing "John buys bread from Walmart"

Although we primarily use deep roles, we continue to use thematic roles as secondary information which is still useful. Each thematic role can be construed as a deep role in an underlying occurrence. For example, the 'agent' thematic role can be thought of as the deep role 'undertaker' (i.e. 'agent') in an occurrence of undertaking, as in 'John and Walmart undertake the purchase occurrence o1' which can be represented as in *Table 3* below.

Participant	Occurrence	Role
c2 (John), c3 (Walmart)	o3	r11 (agent/undertaker)
o2 (an occurrence of purchasing)	o3	r12 (undertaken)

Table 3: Representing "John and Walmart undertake the purchase occurrence o2"

To avoid repetition and allow for re-use of thematic roles across various occurrence types, selection of participants using descriptions can be used. Selection of participants using descriptions, which is useful for many general problems, is described in the next section.

Selection of Participants in Occurrences using Descriptions

In the previous section, participants were denoted extensionally: that is, by indicating the specific identifier of the participant in the occurrence. It is also possible to select participants intensionally, by providing a **description** of the participants; all identifiers that fit the description at a particular time are then viewed as participating in the occurrence at that time.

A description can be viewed as a query that defines a set of criteria and returns a set of resulting identifiers, which may vary over time as the contents on the knowledge-base changes. Descriptions may be created from the following basic types of criteria:

- triplet criteria
- set-definition criteria
- composite, nested criteria

Triplet Criteria

Triplet criteria are so named as they look for identifiers in matching participant-occurrence-role triples; the values (or set or range of values) of two columns are specified in the criterion and the results are the contents of the third column in all rows

[2] The term deep roles is borrowed from Jurafsky and Martin.
[3] The FrameNet project also adopts deep roles for specifying frames for commerce-related lexemes.
[4] In the reading we intend for 'John buys bread from Walmart' take 'buys' to refer to a single, particular occurrence of purchasing, which we can denote by occurrence identifier o2. Other readings are possible.

where the two specified columns match. There are naturally three types of triplet criterion:

- An *occurrence-criterion* specifies the participant and role; all occurrence-identifiers with this participant in that role are returned.
- A *participant-criterion* specifies the occurrence and role; all participant-identifiers in this occurrence with this role are returned.
- A *role-criterion* specifies the occurrence and participant; all role-identifiers for the participant in the occurrence are returned.

For example, to *select concepts named 'Charles'* we could use an occurrence-criterion, followed by a participant-criterion as follows:

1. Occurrence-criterion: select the occurrences (of naming an individual with a name) in which the name given was the symbol 'Charles'. Here we specify our criterion as `Participant='Charles' and Role=r5`, and, given *Table 4* below, we find that occurrence o2 satisfies this criterion.

Participant	Occurrence	Role
c4	o2	r3 (namer)
c3	o2	r4 (named)
(the symbol) 'Charles'	o2	r5 (name)
c4	o3	r4 (named)
(the symbol) 'Elizabeth'	o3	r5 (name)

Table 4: Criterion for finding occurrences in which the name given was 'Charles'

2. Participant-criterion: select the participants who are being named (role r4) in the previously found occurrence(s). Here we specify our criterion as `Role=r4 and Occurrence=o2`, and, given *Table 5* below, we find that concept c3 satisfies this criterion.

Participant	Occurrence	Role
c4	o2	r3 (namer)
c3	o2	r4 (named)
(the symbol) 'Charles'	o2	r5 (name)
c4	o3	r4 (named)
(the symbol) 'Elizabeth'	o3	r5 (name)

Table 5: Criterion for finding participants in occurrence o2 (a naming 'Charles')

Set Definition Criteria

Set definition criteria use the familiar union, intersection, difference, and symmetric-difference set operations.

Composite, Nested Criteria

Criteria may be nested to create *composite, nested criteria*. For example, to find concepts named 'Charles' we could nest an occurrence-criterion within a participant-criterion, to create a single composite criterion of the form:

```
Role=r4 and Occurrence=[Participant='Charles' and Role=r5].
```

The natural reading of this description would be " everyone named 'Charles' ". Given the data in *Table 5* above, this description would resolve to a set of participants containing only one element: the identifier c3.

Examples of Selection of Participants

Assume that we wish to represent that everyone named Charles is a high income earner. We could represent this as in *Table 6* below:

Participant	Occurrence	Role
[Role=r4 and Occurrence= [Participant='Charles' and Role=r5]][5]	o6	r6 (classified)
c7 (high income earners)	o6	r7 (class)

Table 6: Representing "[everyone named Charles] is classified as a high income earner"

To represent the rule that any buyer or seller in a purchasing occurrence is an agent (i.e. undertaker) in that purchasing occurrence, we could use the scheme illustrated in *Table 7* below. Notice that this is a more concise means of representing the rule that buyers and sellers are agents of purchases, rather than the representation shown in *Table 3* above which would be highly space inefficient as it would require separate rows for every purchasing occurrence. The representation shown in *Table 3* above is also prone to:

- slower update transactions as it would require adding additional rows to indicate thematic roles in the occurrence each time a purchase occurrence is added, and
- potential database inconsistency as it would require remembering to commit these rows in the same transaction as the purchase occurrence itself.

Participant	Occurrence	Role
[Role=r8 (buyer) and Occurrence=X[6]], [Role=r9 (seller) and Occurrence=X]	o7	r11 (agent/undertaker)
occurrence X (referred to above)	o7	r12 (undertaken)

Table 7: Representing "[every buyer and seller in a purchasing occurrence] undertakes [the purchasing occurrence]"

Factual Occurrences

Factual occurrences relate to workflow events undertaken by human and software agents. Examples include the occurrence of submitting a form and the occurrence of emailing a client. Factual occurrences may fulfil or violate obligations, create obligations, or have no effect on obligations, though the latter is seldom the case in business.

Ontological Occurrences

The following special occurrence types are defined to facilitate the construction of subjectively defined ontologies:

- Naming occurrences
- Classification occurrences

These are described briefly in the following sections.

[5] Recall from earlier that this description resolves to *all individuals named 'Charles'*.
[6] Further criteria would be specified to indicate that X is specifically an occurrence of 'purchasing'.

Naming occurrences

Naming occurrences take the form *x names y z*, where the participant doing the naming (x) is often unspecified; *x* and *y* are concept-identifiers and *z* is a symbol. "Elizabeth (c4) names (her son)[7] c3 'Charles'" would then be represented as in *Table 8* below:

Participant	Occurrence	Role
c4	o2	r3 (namer)
c3	o2	r4 (named)
(the symbol) 'Charles'	o2	r5 (name)
c4	o3	r4 (named)
(the symbol) 'Elizabeth'	o3	r5 (name)

Table 8: Representing "Elizabeth names (her son) c3 'Charles'"

Here, Charles is c3, Elizabeth was given a new concept-identifier c4, and the occurrences o2 and o3 are occurrences of naming that associate the symbols 'Charles' and 'Elizabeth' with c3 and c4 respectively.

Classification occurrences

Classification occurrences take the form *x classifies y as z*; *x*, *y,* and *z* are concept-identifiers (which have been named using separate naming occurrences). Specifically, x is an identifier for an agent; this may be a person, institution, or software agent. "The United Kingdom Government classifies occurrence o4 as a (valid) purchase" would be represented as in *Table 9* below:

Participant	Occurrence	Role
c5 (the UK Government)	o5	r6 (classifier[8])
o4	o5	r6 (classified)
gov.uk/c6 (purchases)	o5	r7 (class)

Table 9: Representing "The UK Government classifies o4 as a purchase"

Here, occurrence o5 is an occurrence of the UK Government classifying o4 as a purchase. "gov.uk/c6" is a concept-identifier prefixed by a URI; this is used to refer to concepts defined in an external knowledge-base[9]. In the *gov.uk* knowledge-base we could then expect to find the following occurrence (see *Table 10* below), which indicates that c6 is the concept of a 'purchase':

[7] *(her son)* is merely a description of the concept c4. These descriptions, indicated in round brackets, are merely to enhance the readability of the examples, and, for simplicity, the description is not used in the formalization at this stage, though we have illustrated how this may be achieved in the section on *Selection of Participants in Occurrences using Descriptions*.

[8] Here we mean *classifier* as the person or institution making the classification, rather than the sense of *classifier* as a criterion for classifying.

[9] A similar technique is used in Berners-Lee's Semantic Web.

gov.uk knowledge-base

Participant	Occurrence	Role
c6	o173[10]	r4 (named)
(the symbol) 'purchase'	o173	r5 (name)

Table 10: Representing a belief "c6 is a concept named 'purchase'" by the institution `gov.uk`

Notice that classification occurrences are subjective, in that they allow for various parties to make the classification. This would be useful, for instance, where the UK government classifies the occurrence o4 as a purchase, but the German government does not count the occurrence o4 as a purchase. The section on *Normative Occurrences* below illustrates how subjective classifications are useful for defining empowerments.

Normative Occurrences

The following special occurrence types are defined to facilitate the construction of rules, policies, or norms:

- Authorization, forbiddance, and violation occurrences
- Obligation and fulfillment occurrences
- Empowerment and liability occurrences

These are described briefly in the following sections.

Authorization and Forbiddance occurrences

Authorization occurrences take the form *x authorizes*[11] *z*, where x is a concept-identifier for the authorizer, and z is a description[12] of a set of occurrences that are authorized under the authorization occurrence. Any occurrence that fits the description is then authorized. There may or may not be an implication that any occurrences that do not fit the description are forbidden.

Forbiddance occurrences take the form *x forbids z*, where x is the concept-identifier for the forbidder, and z is a description of a set of occurrences that are forbidden. Any occurrence that fits the description is then forbidden. Forbiddances can be restated as violation occurrences.

Violation occurrences take the form *occurrences fitting z violate (forbiddance) p*, where z is a description of a set of occurrences that are forbidden, and p is an identifier for a forbiddance occurrence. An occurrence e violates a forbiddance p if e fits the description z provided for the set of occurrences forbidden under p.

Obligation, Fulfillment, and Violation Occurrences

Obligation occurrences take the form *x obliges z*, where x is a concept-identifiers for the obliger, and z is a description of a set of occurrences that are obliged. For example '[the law] obliges [delivery, from the seller[13], of the item sold to the buyer]'.

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[10] o173 is an arbitrary occurrence identifier for the purpose of this example; the occurrence could have another identifier in the *gov.uk* knowledgebase.

[11] 'Authorizes' is used in the sense of 'allows' or 'permits' here, rather than in the sense 'empowers'.

[12] Descriptions are defined in the section '*Selection of Participants in Occurrences using Descriptions*'

[13] It is not implied that the seller himself must deliver the item, but rather that the item must be sourced from the seller - i.e. originally possessed or owned by the seller.

Rights and duties are represented in terms of obligations:

- An individual has a **right** if they are the beneficiary of an obligation occurrence; that is, if they stand to benefit from an occurrence described under the obligation. Using concepts from the theory of case roles (semantic roles) an individual stands to benefit from an occurrence if they are in the 'beneficiary' thematic role of that occurrence. An individual is a beneficiary, for example, when they are an intended recipient in a 'sending' occurrence where something beneficial is sent to them. An obligation in the form provided above may be restated as a *w has a right to x* where w is a beneficiary alluded to (i.e. indirectly mentioned) by z, and x is the description z constrained further to exclude occurrences that are not in favour of (i.e. to the benefit of) w. For example, '[the buyer] has a right to [delivery of the item sold to the buyer]'.
- An individual has a **duty** if they are the obliged party under an obligation occurrence. An obligation in the form provided above may therefore be restated as a *y has a duty to z* where y is the obliged party alluded to by z and z is still the description of a set of occurrences that are obliged. For example, '[the seller] has a duty to [delivery of the item sold by the seller to the buyer]'.

To continue our example consider an obligation occurrence o1 of a seller to deliver the purchased article in a purchase to the purchaser of that purchase. Notice how this obligation is purposefully vague and that delivery can be, for instance, by post or by email. Both successful posting occurrences and successful emailing occurrences would satisfy the obligation, assuming of course that we took both 'successful posting' and 'successful emailing' to refer to composite occurrences that entail both *sending* by party A and *receiving* by party B. Since both posting occurrences and emailing occurrences of this sort could be classified as delivery occurrences, and they fit the description associated with the obligation, they would therefore fulfil the obligation[14]. Note that the specific obligation o1 does not cease upon fulfillment as other sellers need to satisfy o1 under their respective sale agreements (sale occurrences). So fulfilling the obligation by an obliged party does not entail that the obligation ceases for all parties, only that it ceases (or is temporarily suspended) for the party that fulfilled it.

Participant	Occurrence	Role
c1	o1	r14 (obliged party)
[Role=r16 (recipient) and Participant= [Role=r8 (buyer) and Occurrence=X]], [Role=r17 (received item) and Participant= [Role=r8 (bought item) and Occurrence=X[15]]] INTERSECTION the set of occurrences classified as deliveries by a certain institution	o1	r15 (obliged occurrence)

Table 11: Representing "an obligation of a seller to deliver the purchased article in a given purchase to the buyer in that purchase"

Fulfillment occurrences take the form *occurrences of z fulfil (obligation) p*, where z is, as for obligations, a description of a set of occurrences that are obliged, and p is an identifier for an obligation occurrence. An occurrence e can only fulfil an obligation p if e fits the description provided for the set of occurrences obliged under p.

[14] Not all postings and emailings are of this sort; more often 'postings' and 'emailings' are considered in the sense that entails only sending and not delivery.

[15] An additional criterion would be needed to specify that X is an occurrence classified as a purchase by a certain institution. This criterion has been omitted for simplicity.

Obligations often entail that any occurrences that make the fulfillment of the obligation impossible are forbidden (under forbiddance occurrences, defined earlier). These occurrences may include such things as the passing of a deadline or the happening of a mutually exclusive occurrence. The happening of such an occurrence violates the forbiddance and consequently violates the obligation.

Empowerment and Liability Occurrences

Jones and Sergot propose the notion of empowerment or institutionalized power, and introduce a connective allowing a state of affairs to 'count as, according to a given institution ' another state of affairs. We provide an alternative, but in many senses similar, implementation of empowerment through the use of classification occurrences (defined earlier).

Empowerment occurrences take the form *x is empowered by (institution) y to do c by d*, where x is an individual or described set of individuals, y is an institution, c is a class or category of occurrences, and d is a description of a set of simple or composite occurrences. Specifically, this empowerment means that if an occurrence e fits the description d, the institution y classifies the occurrence e as being in the class c. For instance, an insurance company may classify a claim as being a valid claim occurrence only where the occurrence of submitting a claim is in respect of a set of insurable events.

Liability[16] *(making liable) occurrences* take the form *x is liable under (institution) y to do c by d*, where x is an individual or described set of individuals, y is an institution, c is a class or category of occurrences, and d is a description of a set of simple or composite occurrences. Specifically, this liability means that if an occurrence e fits the description d, the institution y classifies the occurrence e as being in the class c.

It can be noticed that empowerment to and liability to are equivalent in that both involve the assertion of a classification by an institution over a set of described occurrences; that is, both have classification occurrences which underlie them. Empowerment and liability differ in the following way:

- The classification that results under an empowerment will result in individual x acquiring **rights** as previously defined - that is becoming the beneficiary of an obligation or obligations of another party (where such obligation arises as a result of the classification occurrence).
- The classification that results under a liability will result in individual x being encumbered by **duties** as previously defined - that is becoming the obliged party under an obligation or obligations of another party (where such obligation arises as a result of the classification occurrence).

Clearly, many classifications result in a party acquiring both rights and duties, and thus a single classification occurrence may be classified as both an empowerment and a liability. Empowering and making liable are therefore occurrences under different descriptions, and the descriptions are not mutually exclusive.

The combination of obligation occurrences and classification occurrences, in combination with temporal concepts, can be used to represent a substantial set of normative concepts relating to e-commerce contracts. Specifically, the Hohfeldian concepts of right, duty, power and liability can be represented in a manner similar to that illustrated by Kanger. No-right, liberty, disability, and immunity may be represented by absence or non-existence of pertinent obligations occurrences (negation by failure) or by specific forbiddance of such occurrences (explicit negation).

[16] 'Liability' is used in a sense related to, but not identical to, that used by Hohfeld, as opposed to in the accounting sense of liability.

Example of an Obligation from the Insurance domain

As mentioned earlier, occurrences may occupy discontinuous intervals of time. Consider for example the policy that 'the system must charge a premium of $10 on the last day of each month to an insured[17] who is not deceased'. Noticing that the modal 'must' often implies obligation occurrences, this policy can be restated as an obligation occurrence of the form 'the system is obliged to charge[18] a premium of $10 on the last day of each month to a (particular) insured party who is living'. *Figure 1* below illustrates the time intervals associated with each of the relevant occurrences with a solid bar. Notice that a given time-point can fill multiple roles: for instance t6 is the occurrence time of o6, the dying of the person, and t6 is also the ending time of the occurrence o3, which is the occurrence of the person being classified as insured by the company.

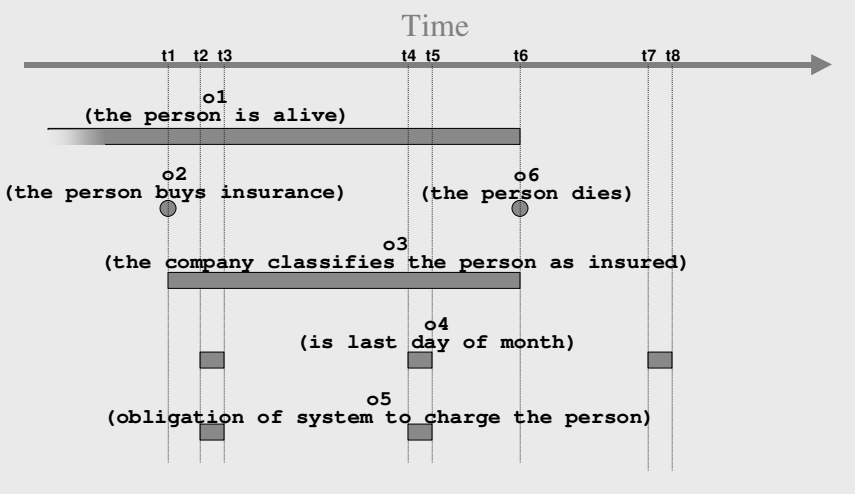

Figure 1: A discontinuous obligation of an insurance system to charge an insured individual a premium on the last day of the month during the latter's lifetime.

[17] For simplicity here, take the reading of 'an insured' to be a particular, insured person (e.g. c1), rather than any insured person.

[18] Notice that 'charging the insured' implies the imposition of an obligation on the insured. However, we will not concern ourselves with the obligation of the insured to pay their premium here; rather we will restrict ourselves to considering the obligation of the system to charge the premium.

How an Occurrence-based System Executes

As is evident from the example above, the system (effectively, a software agent) is itself a party that is subject to obligations (effectively 'liveness' properties) and authorizations/forbiddances (effectively 'safety' constraints).

The goal of a system is to fulfil its obligations. The system fulfils its obligations by triggering occurrences which fit the descriptions specified in its obligations. It may use whatever scheme it wishes to trigger the occurrences it is capable of triggering, as long as the occurrence fits the description associated with the obligation. For example, if the system has an obligation to 'notify the user' it can trigger an occurrence of 'send email' or an occurrence of 'display notice on web-page' as it is capable of performing each of these occurrences and each of those occurrences satisfies the description 'notifying the user'. The system's activities are therefore guided by its obligations, as well as by what occurrences it knows how to enact that fit the descriptions associated with its obligations. The obligation may be fulfilled at any time during the time interval in which the obligation applies. Once fulfilled, the obligation either ceases completely to apply to that party, or alternatively is temporarily suspended from applying to that party until it is next activated - the latter is the case in recurring obligations which may be activated periodically (e.g. every 30 minutes) or aperiodically (e.g. on the 1st of each month, which is aperiodic since the lengths of the months vary).

The system must further ensure that it does not trigger an occurrences that violate forbiddances (i.e. occurrences that fit the description associated with a 'forbids' occurrence). Should it violate a forbiddance, it is usually subject to a secondary obligation to rectify the violation in some way. The system goes about attempting to fulfil this secondary obligation in order to satisfy its goal, though it may fail again and incur a tertiary obligation, and so on.

Summary

We have presented a framework for specifying and executing e-commerce systems, based on the notion of individuated occurrences. These occurrences specify the system facts (e.g. workflow events), ontology, and norms; the latter guide system execution, resulting in the creation of new facts and rules as the system fulfills its obligations.