A CONSOLIDATED ENTERPRISE REFERENCE MODEL
Integrating McCarthy's and Hruby's Resource-Event-Agent Reference Models

Wim Laurier, Maxime Bernaert and Geert Poels
Department of Management Information Systems and Operations Management
Faculty of Economics and Business Administration, Ghent University, Tweekerkenstraat 2, 9000 Ghent, Belgium

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Abstract: This paper introduces a new Resource-Event-Agent (REA) reference model that integrates the transaction and conversion reference models provided by McCarthy, which aimed at designing databases for accounting information systems, and Hruby, which aimed at software development for enterprise information systems, into a single conceptual model that accounts for both inter-enterprise and intra-enterprise processes. This consolidated reference model was developed to support data integration between multiple enterprises and different kinds of enterprise information systems (e.g. ERP, accounting and management information systems). First, the state of the art in REA reference models is addressed, presenting McCarthy's and Hruby's reference models and assessing their ability to represent exchanges (e.g. product for money), transfers (e.g. shipment) and transformations (e.g. production process). Second, the new, consolidated REA enterprise reference model is introduced. Third, object model templates are presented, demonstrating that the consolidated REA reference model is able to represent exchanges, transfers and transformations, where McCarthy's and Hruby's reference models can each only represent two of these features.

1 INTRODUCTION

In the past, business modelling focused on the enterprise's value chain as the core structure in business that needed to be supported by information systems. These value chains consist of value activities (e.g. a production process). The value chain of a company is embedded in a value system, which includes the value chains of suppliers and customers. (Porter and Millar, 1985) The focus of business modelling on the enterprise's value chain resulted in the development of enterprise-wide information systems. However, a continuously faster globalizing world economy and increasing cooperation among supply chain partners increases the need to model the entire value system (e.g. supply chain) and not just individual players within it. (Giachetti, 1999)

We can currently discriminate two kinds of reference models. First, models that support intra-enterprise processes and abstract from interactions between trading partners. (Jansen-Vullers et al., 2003) Second, models that support inter-enterprise transactions and abstract from the internal business of the involved partners. (Shin and Leem, 2002)

What is needed is a reference model that allows each enterprise taking part in a value system to develop its own value chain information system and at the same time supports the creation of system interoperability and information sharing amongst supply chain partners.

In this paper, a new enterprise reference model that is based on the REA enterprise ontology (Geerts and McCarthy, 2002, Geerts and McCarthy, 2004) is proposed. The reference model integrates both enterprise perspectives (i.e. transactions and processes) in a single reference model. This reference model integrates the features of the reference models in McCarthy's (1982) foundational REA article, which focuses on transactions between individual enterprises by representing the exchange of resources (e.g. money for product) and the resulting resource transfers between trading partners, and Hruby's (2006) book on business patterns design, which focuses on the processes inside an enterprise by representing exchanges and conversions (i.e. process input becomes process output).

Section 2 discusses McCarthy's and Hruby's REA reference models and their specific

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characteristics. Section 3 presents the new, consolidated REA reference model and a number of object models for transfers, exchanges and transformations that instantiate this consolidated reference model. Section 4 presents conclusions.

2 STATE OF THE ART

The REA ontology knows three main primitives, namely economic resource, economic event and economic agent, which are abbreviated to resource, event and agent in the remainder of this paper. *Resources* in the REA ontology are defined as goods, services or rights that have utility and are scarce and under the control of a legal or natural person (McCarthy, 1982, ISO/IEC, 2007). *Events* are occurrences in time that relate subsequent process states to each other and involve gaining (i.e. increment) or losing (i.e. decrement) control over economic resources (McCarthy, 1982, ISO/IEC, 2007). *Agents* are natural or legal persons (e.g. employee, customer) that are accountable for, participate in or initiate economic events.

2.1 McCarthy's Reference Model

Fig. 1 shows a modernised version of McCarthy's foundational reference model (McCarthy, 1982) as it appears in ISO's business transaction scenario standard (ISO/IEC, 2007). This model differs from the initial model by decomposing the n-ary 'control' relation in two binary participation (i.e. agent-event) relations, conforming to Weber's critique (Weber, 1986), and the merger of the economic agent and its subclass economic unit in the AGENT class.

Figure 1: McCarthy's REA Reference Model.

The STOCK-FLOW association between the RESOURCE and EVENT classes in fig. 1 shows which resources are involved in and affected by which events. The INCREMENT-DECREMENT association in fig. 1 represents the duality relationship between two events (i.e. one increment and one decrement). This duality balances the changes in resources due to events representing the principle of economic reciprocity, which requires adequate compensation (i.e. increment event) (e.g. payment received) for lost resources (i.e. decrement event) (e.g. resource shipments). (McCarthy, 1982) The EXCHANGE-INSIDE_PARTY association reveals the agent whose view determines which events are increments and which are decrements. The EXCHANGE-OUTSIDE_PARTY association relates the inside party's counterparty to the economic event.

With McCarthy's foundational reference model, exchange and transfer object models can be constructed. Fig. 2 shows a template that integrates the views of both trading partners. We recognise two resource transfers with opposite directions (i.e. one represents a cash inflow for the vendor and a cash outflow for the buyer; one represents inventory goods inflow for the buyer and a goods outflow for the seller). We also discriminate two mirrored exchange templates (i.e. 'cash for goods' in the buyer's purchase and cash disbursement duality, 'goods for cash' in the vendor's sale and cash receipt duality).

Modelling a transfer of resources between the inventories of two trading partners, a transfer model relates the corresponding mirrored events in an exchange with each other. This mirroring relation is mediated by a resource object for which one event represents an inflow (e.g. PURCHASE) and the mirroring event represents and outflow (e.g. SALE). Although the agents connected to the mirrored events are the same, the inside and outside party roles are switched, which represents the opposing economic interests of the trading partners (i.e. SELLER and BUYER). Also note that the mirroring relation between the buyer's view on an event and the vendor's view on the same event is implicit in fig. 2. The downside of this representation is that real events are artificially decomposed (e.g. purchase and sale are actually two views on the same event).

2.2 Hruby's Reference Model

Fig. 3 shows Hruby's (2006) reference model. By explicitly discriminating increment and decrement events, it differs from McCarthy's reference model, which chooses to represent increment and decrement as roles of events and not as kinds of events.

Hruby's reference model also incorporates provide (i.e. PROVIDER-PROVIDE) and receive (i.e. RECIPIENT-RECEIVE) relationships that connect

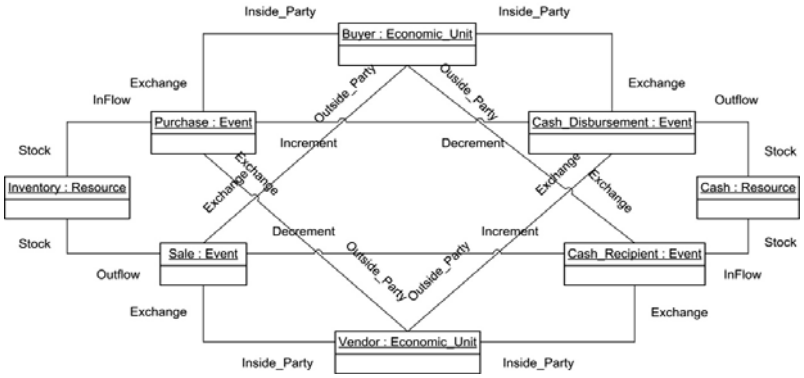

Figure 2: McCarthy's Integrated View Exchange.

Figure 3: Hruby's REA Reference Model.

agents with increment and decrement events. The provide relationship relates the event to the agent that experiences a resource decrement and the receive relationship relates the event to the agent that experiences a resource increment. Consequently, a provide relationship relates a decrement event to the agent that experiences the decrement (i.e. inside party in McCarthy's model) and a receive relationship relates an increment event with the agent that experiences the increment (i.e. inside party in McCarthy's model). Table 1 summarises these view relations between agents and events, and the conceptual differences for the participation relation (i.e. agent-event) in McCarthy's and Hruby's reference models.

Table 1: Provider and Recipient as Inside and Outside Agent.

		Event	
		Increment	**Decrement**
Agent	**Provider**	Outside Party	Inside Party
	Recipient	Inside Party	Outside Party

The duality (i.e. DUAL_TO-DUAL_TO) relation between the INCREMENT_EVENT and DECREMENT_EVENT classes is identical to the duality in McCarthy's model except for the fact that it relates distinct classes and not one event class that plays distinct roles. Finally, Hruby decomposes McCarthy's stock-flow relation into consume (i.e. OUTFLOW-CONSUME), use (i.e. OUTFLOW-USE) and produce (i.e. INFLOW-PRODUCE) relations. The difference between the use and consume outflow relations is that use relations temporary occupy a resource without affecting its ability to participate in subsequent decrement events, while consume relations indicate that a resource is no longer available for further decrements. Hence, Hruby incorporates part of McCarthy's model logic in his reference model (i.e. events in an outflow role are decrement economic events and events in an inflow role are increment economic events).

The basic value creating processes in an enterprise can be categorised as acquisition, conversion and revenue generating processes, which construct an enterprise's value chain (McCarthy, 2003). Fig. 4 integrates an acquisition process with

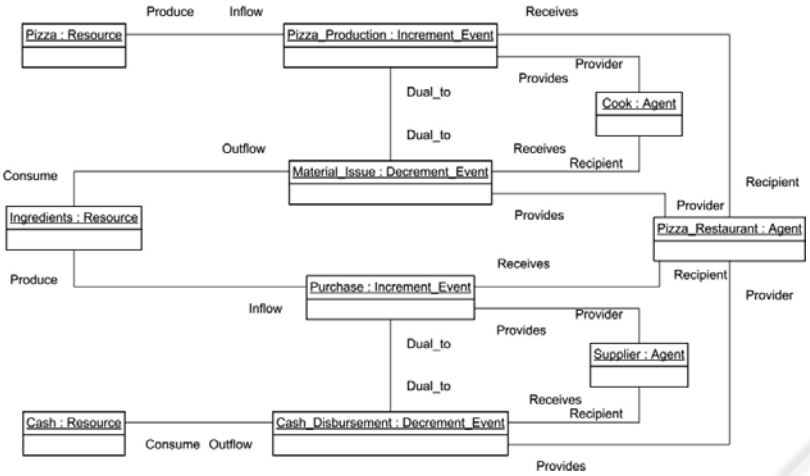

Figure 4: Hruby's REA Value Chain.

a conversion process. The acquisition process shows how ingredients are purchased in return for cash.
The conversion process represents the conversion of ingredients into pizza. The acquisition part of fig. 4 shows the exchange of CASH and INGREDIENTS between the PIZZA_RESTAURANT and its SUPPLIER. The conversion part of fig. 4 shows the transformation of INGREDIENTS into PIZZA that is performed by the COOK for the PIZZA_RESTAURANT.

Hruby's exchange template is fairly identical to McCarthy's articulation (i.e. part of fig. 2). The main difference is that the increment and decrement roles in McCarthy's model are replaced by specific classes. The inside and outside party roles on the participation relations in McCarthy's model have also been replaced by provider and recipient roles.

The conversion model that represents (part of) a production process, on the other hand, is not incorporated in McCarthy's version of REA. The conversion is represented as an implicit exchange between process inputs (i.e. INGREDIENTS) and process outputs (i.e. PIZZA), where the employer (i.e. PIZZA_RESTAURANT) provides the inputs and receives the outputs from the employee (i.e. COOK) and the employee receives the inputs and provides the outputs to the employer. The conversion process itself is modelled as a duality between one or more decrement events that use or consume input resources and one or more increment events that produce output resources. The downside of this kind of representation is that conversion processes are represented as exchanges, while employees never own the resources they work with, and that conversion processes are artificially decomposed in a collection of increment and decrement events.

3 CONSOLIDATED REFERENCE MODEL

A remarkable feature of both McCarthy's and Hruby's reference models is that they both use the agent concept to model trading partners and event performers. The downside of this choice is that trading partners cannot be explicitly discriminated from pure event performers (e.g. the trucker cannot be discriminated from the enterprise that ships the goods). To allow for this discrimination, we reintroduce the concept of economic unit that was removed from McCarthy's original reference model as a synonym for the agent concept. Therefore, the agent and economic unit concepts need to be redefined. We redefine an *Agent* as the natural person that executes the event and an *Economic Unit* as the legal or natural person that loses or gains control over resources in decrement and increment events respectively. Consequently, economic units, which were originally defined as a subclass of Agents (McCarthy, 1982), determine the scope of the context in which economic activities take place.
This new definition also fits McCarthy's original model, where economic units are inextricably bound with the inside party role that determines which events are classified as increments (i.e. gaining control over resources) and decrements (i.e. losing control over resources). Therefore, we consider our economic unit and agent definitions more robust descriptions of semantics that were already implicitly present in the original REA model.
Fig. 5 reflects the key role of the economic unit concept in our reference model. In this reference

Figure 5: Our REA Reference Model.

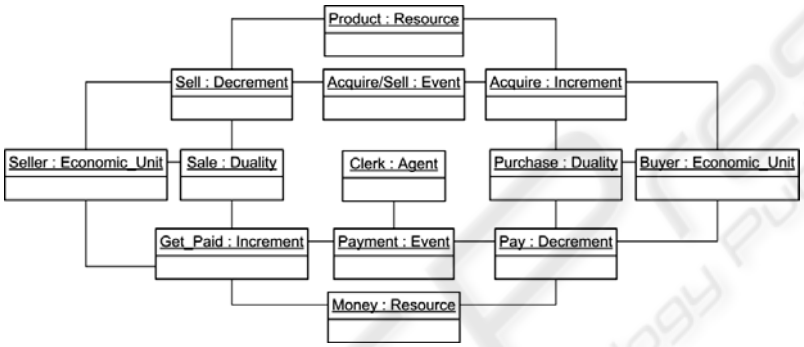

Figure 6: REA Consolidated View Exchange Model.

model, the economic unit defines the duality that connects the explicitly modelled increment and decrement roles for the event that forms the centre of our reference model. The agents in this reference model participate in events, meaning that they execute events without experiencing their economic consequences (i.e. gaining or losing control over resources). These consequences are experienced by the economic units and explicitly represented by the INCREMENT and DECREMENT classes in the reference model that mediate between the ECONOMIC_UNIT and the RESOURCE over which it gains or loses control. The reference model (fig. 5) also reveals that a single EVENT can be viewed as an increment and decrement at the same time, by the same or different economic units.

Fig. 6 shows the integration of a transfer and an exchange into a consolidated view exchange model. It shows two mirrored dualities (i.e. PURCHASE and SALE) and two transfer events that connect them to each other (i.e. ACQUIRE/SELL and PAYMENT). The PURCHASE duality shows how the BUYER exchanges MONEY for PRODUCT, where the SALE duality represents how the SELLER exchanges PRODUCT for MONEY. The ACQUIRE/SELL event shows that ACQUIRE and SELL are in fact two roles of the same event. Similarly PAY and GET_PAID are two roles of PAYMENT. The ACQUIRE role is assigned to the ACQUIRE/SELL event by the BUYER, while the SELL role is assigned by the SELLER. Likewise, the GET_PAID role is assigned by the SELLER and the PAY role by the BUYER.

The exchange duality models the exchange (e.g. PURCHASE), which involves a resource inflow (i.e. ACQUIRE) and a resource outflow (i.e. PAY), from the viewpoint of a single economic unit. Taking the buyer perspective, the economic unit (i.e. BUYER) defines the DUALITY and the INCREMENT and DECREMENT roles for the resource transfer events involved. Such a transfer event (e.g. a MONEY transfer (i.e. the PAYMENT event)) is perceived by a BUYER and a SELLER. The PAY/GET_PAID decrement/increment role represents the BUYER/SELLER‘s view on the PAYMENT event. The CLERK object represents the person that executes the payment regardless of whether he/she experiences the economic consequences of this action.

Finally, fig. 7 shows a transformation template in which transformation inputs are transformed into outputs. The template shows that the TRANSFORMATION event takes place inside a single economic unit (i.e. EMPLOYER) and that both the

inputs and outputs are owned by the EMPLOYER, without a transfer of ownership during the conversion process. This representation is closer to reality than Hruby's implicit ownership transfer during the conversion process. The template also shows that an EMPLOYEE performs the TRANSFORMATION event. For representing an entire production process, subsequent events can be modelled using the transformation template, creating multiple events that are all related to the same economic unit (i.e. the enterprise in which they take place) and share one or more resources (i.e. the output of one conversion process is the input for a subsequent one). At the start of such a process model we find one or more exchange templates (fig. 6) that represent the acquisition of the process inputs and at the end we find one or more exchange templates that represent how revenue is generated from process outputs.

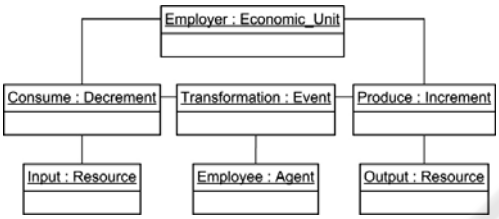

Figure 7: REA Transformation Event Model.

4 CONCLUSIONS

The consolidated reference model presented in this paper supports inter-enterprise (e.g. for transaction recording systems) and intra-enterprise (e.g. for production process monitoring systems) data, as both kinds of systems can now rely on the same reference model.

Key to the integration of the existing REA reference models was the partial redefinition of the economic unit and agent concepts. The redefinition of the economic unit concept allows models to represent previously implicit semantics related to the control over resources. Where previously the view of every enterprise was represented in a separate model, the scope of different enterprises can now be represented in a single model via the economic unit concept and its relations with resources, events and agents. This explicit representation of enterprise boundaries allows for a central administration of transactions between and transformations within enterprises.

Where the redefinition of the economic unit and agent concepts facilitates the integration of data across enterprise boundaries, the intuitive event concept eases process modelling. Together, they can help improve product traceability by identifying the event chains (i.e. transfer and transformation events) that lead to the products, irrespective of the number of enterprises (and enterprise information systems) in which products and their constituents have their origin. Such product tracing infrastructure might support product authentication in the battle on counterfeit and other supply chain intrusions (e.g. food safety scandals) (Bechini et al., 2008). It may also help to trace the origin of money (e.g. drugs money) in the battle against money laundering.

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