Modeling Time in REA/REAL Databases: Planning and Availability

Daniel E. O'Leary
University of Southern California
3660 Trousdale Parkway
Los Angeles, CA 90089-1421

Oleary@usc.edu

213-740-4856
213-747-2815 (fax)

Words = ~ 4800 words
Figures = Six figures

June 1998
Revised - July 1999

Acknowledgements: This paper was presented at SMAP 1999. The author wishes to acknowledge the comments of the participants. In addition, the author would like to thank the SMAP referees for their comments on an earlier version of this paper.

Comments are Solicited

Keywords: REA databases, REAL Databases, Time

Modeling Time in REA/REAL Databases: Planning and Availability

Abstract

Modeling time to meet enterprise requirements in REA requires two orthogonal concepts: valid time and transaction time. Valid time can be multidimensional, including historical, planned and plan instantiation time. Transaction time is when the information is recorded.

Valid time is proposed as an addition to the REA model for each of resources, events and agents. Transaction time can be associated with each REA tuple. Transaction time can be particularly critical from a control perspective, e.g., providing information for intrusion detection systems, and performance monitoring perspective, providing information that can be used to measure efficiency. In addition, given transaction time, the database can be “rolled-back” to the world as of some previous time.

Historical valid time-based information can be captured to allow determination of resource, agent and location availability for planning. Valid time can also be used to capture time for events using either a single dimensional historical view or a multidimensional one that accounts for an enterprise planning model of time. This allows capture of planning event information, and linkage in a dual relationship to actual plan instantiation of planning events. Sequentially, generally, availability time proceeds planned usage time, which proceeds plan instantiation time.

The planning event, along with the resources and agents, becomes the initiated basis of analysis, and provides an alternative type of “duality.”

Modeling Time in REA/REAL Databases: Planning and Availability

I. Introduction

Researchers have found that “time stamps” indicating when an event took place and for how long, are sufficient to keep track of historical time event information in an REA (**R**esources – **E**vents – **A**gents) structure (McCarthy 1982) and its extensions (e.g., Hollander et al. 1996) such as REAL (REA– **L**ocations). Financial statements can be derived from historical data. In addition, more extensive and detailed, decision-facilitating queries can be answered based on that historical information.

However, four recent developments suggest that REA be extended in order to meet emerging requirements. First, as systems have become more computerized the “transaction” time, the time that an event or transaction is recorded, is emerging as an important source of efficiency and control information. Using transaction time, when data was entered into the database can be used to provide insight into worker efficiency at processing event information or to detect fraudulent activity (e.g., Tenor 1988). Second, increasingly resources, agents and locations are becoming time constrained. For example, corporations are banding together in virtual organizations that employ resources, agents or locations for only limited periods of time, in order to maximize marginal revenues from those assets. In order to accomplish this task, there is a need to have information that relates to general availability of resources, agents and locations (e.g., 8 am to 5 pm). Third, emerging enterprise concepts need a model of planned time that extends notions of historical time, as part of a “valid” time model. Not only is there interest in the general availability of resources, agents and locations, but given that information, what plans have been established. Plans are events, as are instantiations of those plans in order to gather data on planning effectiveness. Further, the different models of time can be used together. For example, the difference between transaction time and historical valid time or the temporal order may provide insight into fraudulent activity. Fourth, the importance of two types of time, transaction time and valid time (the time over which information is valid) has been recognized in two American National Standards Institute (ANSI) change proposals for SQL (Snodgrass et al. 1996a and Snodgrass et al. 1996b).

In order to meet these emerging enterprise requirements, and provide sufficient information to facilitate controls and monitoring, additional models of time are needed. The purpose of this paper is to generate some of the requirements and characteristics of such enterprise time models.

Plan of This Paper

This paper proceeds as follows. Section II provides a brief background for REA database systems and previous treatment of time in REA systems. Section III discusses the forces behind generation of an extended model of time in REA. Section IV summarizes some database models of time, and distinguishes between transaction time and valid time. Section V investigates the use of transaction time and valid time in REA. Section VI discusses the implementation of the time models. Section VII provides a basis of evaluation of the model. Section VIII investigates some extensions and briefly summarizes the paper.

II. REA Database Systems and Time

This section briefly reviews REA and their extensions, their need for time and their current models of time.

REA and REAL Database Systems

The REA (Resources-Events-Agents) model was proposed by McCarthy (1982) and later modified by Hollander et al. (1996) as the REAL (Resources -Events-Agents-Locations) model. Both models provide templates of economic events, based in part on fundamental modeling concepts proposed by Chen (1976). Much of the extensive literature growing up around REA is summarized in Dunn and McCarthy (1997).

For the remainder of the paper I will focus on REA. REA focuses on modeling the concepts (e.g. resources) on which information flow is based, rather than modeling information artifacts (e.g., checks, invoices and ledgers). Under REA, required information artifacts are considered views, rather than influencing the underlying data model. Ultimately, if the model is built correctly, any particular view can be generated from the underlying data model. Accordingly, enterprises can integrate a wide variety of data in the enterprise database, including financial and non-financial data.

When it was first presented, REA was based on entity relationship database templates relating each of economic resources, economic events and internal and external agents (participants). Now other approaches could be used for the REA template, such as UML.

REA employs concepts of outflow of economic resources, inflow of economic resources, duality relationships between sets of events and participants to events (agents). The general REA format is in figure 1. The REA format would be extended to include event location.

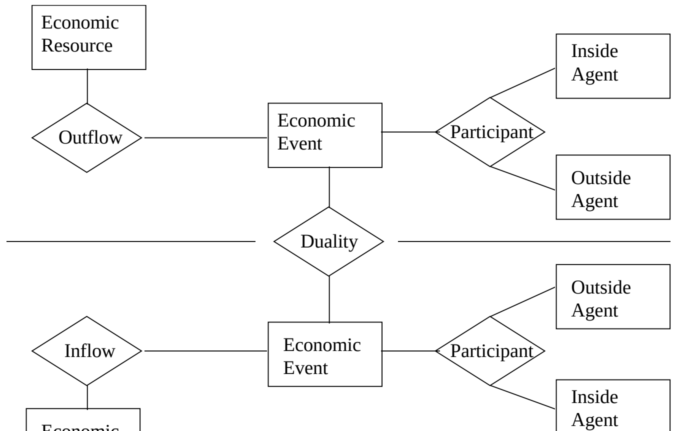


Figure 1
General REA Model

A specific example of the REA template for purchasing goods is given in figure 2. Each event, such as a purchase or cash disbursement has a resource (or set of resources) that is either incremented (inventory) or decremented (cash). In addition, each event has an inside agent (e.g., buyer) and an outside agent (vendor). For a purchase, the inside agent is responsible for the purchase of the resource, while the outside agent is responsible for supplying the inventory. For a cash disbursement, the inside agent is responsible for the cash payment, while the outside agent receives the cash.

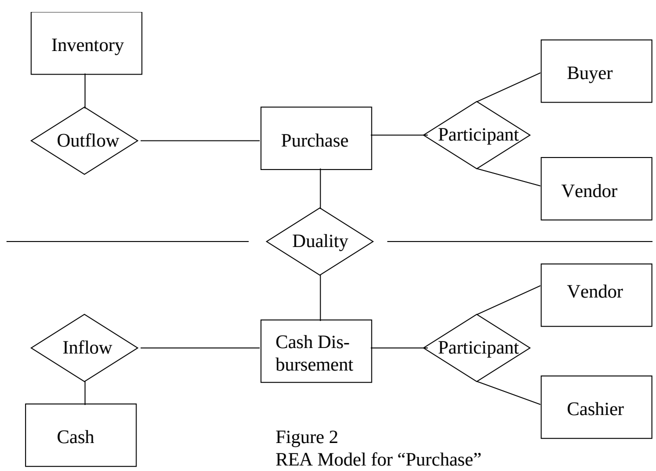


Figure 2
REA Model for "Purchase"

Historical Perspective Originating in REA

When introduced, REA focused on historical values of information. Events occurred and it was the job of REA to record information about those events. This section traces the development of that historical perspective.

The entity relationship (ER) model was first introduced into accounting in a manner where there were substantial parallels with traditional accounting (e.g., McCarthy 1979, p. 669). ER was designed to capture an historic "slice" of reality. ER models departed from traditional accounting systems by breaking away from traditional double entry capture of data and traditional artifacts, such as charts of accounts. In so doing the scheme that was developed (McCarthy 1979, p. 668) " … was not limited by the principles of double entry and monetary measurement, but (was allowed) … to assume more of the multidimensional and disaggregated aspects proposed by 'events' accounting theorists …." However, data captured was historical data. As a result, there was a need for an event time stamp (McCarthy p. 679).

Resources-Events-Agents (REA) presented by McCarthy (1982) extended the ER model to enterprise applications. As noted by McCarthy (1982) "In an accounting context, the availability of multiple views would allow diverse and flexible use of economic transaction data …." Accordingly, although REA clearly and importantly extended the earlier ER work, there was a continuation with historical transaction data.

Since the original work by McCarthy on REA, if they considered time, researchers focused on the time that events occurred – a perspective requiring historical time. For example, Gal and McCarthy (1986) capture the date and time that a purchase payment occurred. Hollander et al. (2000, p. 47) are among the few to explicitly discuss the role of time in REA. They use an event's “absolute” time as a basis to record the time at which an event occurred and how long it took for the event to transpire:

> *When did an Event occur? This involves determining each event’s time of occurrence, relative to other events in the process, as well as the absolute time of the event. The absolute time of an event refers to the date/time stamp for an event and how long it took for the event to transpire.*

As an example, Hollander (1996, p. 93) note,

> *… (the event) Take Customer Order will have an absolute time when it occurred (e.g., December 12, 1994, 4:43 PM) and an absolute length of time (3 minutes and 42 seconds).*

The need for a more explicit and extensive model of time changed when REA was extended to data warehouse settings in REAL-D (O’Leary 1999). Data warehouses employ a model of time in order to facilitate timely decision analysis of historical data, and answer questions such as, e.g., “What if ….” In particular, REAL-D employs a model of time that included date, time, day of week (e.g., Monday), month, year, each as specific attributes to facilitate roll-ups of decisions over time. This was one of the first indications that models of time need to be incorporated into REA to meet particular needs. However, REAL-D still maintained a single dimension, historical perspective.

III. Forces for a Model of Time in REA

There have been three primary forces that lend themselves to the inclusion of time in REA: changing nature of monitoring and controls, virtual organizations and enterprise resource planning systems.

Changing Nature of Monitoring and Controls

Paper is being driven out of today’s computer-based systems. As a result, performance monitoring, that use to depend on paper-based measures (e.g., documents processed), has limited application. Accordingly, there is a need to capture additional information, such as, when an event was processed, and how long it took, in order to monitor performance.

In addition, historically, fraud detection also employed substantial paper-based analysis. Since that paper is not longer available or does not provide timely enough feedback, companies and researchers are developing intrusion – detection systems that exploit available data to try to determine anomalous situations, e.g., fraud (Tenor 1988 and O'Leary 1992). One such potential indication of fraud might be the length of time between when an event took place and when it was recorded. Unfortunately, since REA does not differentiate between time to record an event and the event time, information is not readily available for use to either monitor or control.

Further, in some cases decision makers may want to "roll – back" to some particular time, in order to see what was the state of the world at some previous time, possibly to evaluate decision making. In order to so, would require transaction time on every tuple.

Virtual Organizations

Goldman et al. (1995) defined a virtual organization as one where

> *complementary resources existing in a number of cooperating companies are left in place, but integrated to support a particular product effort for as long as it is viable to do so …. Resources are selectively allocated to the virtual company if they are underutilized or if they can be profitably utilized there more than in the 'home' company.*

Virtual organizations are formed by employing resources, agents and locational assets from their home organizations, in projects with other organizations. In order to structure virtual organizations, availability information is necessary for each asset. For example, virtual organizations need to know the available work hours for internal agents (8am to 5pm, Monday through Friday), before they can determine what assets are available to be shared with virtual organizations. As a result, it can be important for organizations to have time-based information regarding each of its resources, agents and locations. Time based information can include start time and end time that a resource is available, *or equivalent information.*

Enterprise Resource Planning Models

Enterprise resource planning (ERP) models have changed and have changed information needs. Initially, enterprise models started out as little more than transaction processing models, concerned only with historical data. However, increasingly, enterprise models are being pushed in many other directions by ERP systems, such as SAP. In particular, one of the key functions of ERP systems is that of planning (e.g., Whang et al. 1995). When "planning" information is required, information needs change. For example, planning information is likely to gather future oriented information, such as schedule information or planned materials usage.

IV. Models of Time

Database researchers have used two different models of time (continuous and discrete) to capture valid time and transaction time requirements.

Continuous vs. Discrete Time (McKenzie and Snodgrass 1991)

Continuous or discrete models can be used to represent time. Both models assume a linear ordering. If a continuous model of time is used then time is seen as isomorphic to the real numbers, and each real number corresponds to a point in time. If a discrete model of time is used then time is seen as isomorphic to the integers, and each integer corresponds to a non-decomposable unit of time, where the units of time have arbitrary, but constant duration (granularity). Typically, enterprise-based systems employ a nested granularity of year, month, day, hour : minute. If January 1, 12:00 am, 2000 is the base year of interest, a discrete model of February 1, 11:00 am, 2000 could be measured <2,1,11,2000>.

Periodicity (McKenzie and Snodgrass 1991)

Another characteristic of modeling time is data periodicity, that captures the regularly occurring nature of events, resource use or agent use. For example, work time might range from 8 am to 5 pm, Monday through Friday. As a result, a typical enterprise facility has periodicity.

Valid Time vs. Transaction Time (McKenzie and Snodgrass 1991)

Although time has received only limited attention in REA, time has received substantial attention in database research (e.g., Bubenko 1977 and McKenzie and Snodgrass 1991). This has led to the development of a temporal data model (McKenzie and Snodgrass 1991, p. 502) that "… would store, along with information on entities and relationships, both when information was valid in the real world and when that information was recorded in the database." Both valid time and transaction time can employ fields capturing the start or finish of activities, or equivalent representation.

Valid time, also called intrinsic time by Bubenko (1977), is when the information is valid, e.g., when an event occurred. Transaction time is when the event was captured, or the resource, agent or location information was established. Bubenko (1977) referred to transaction time as extrinsic time.

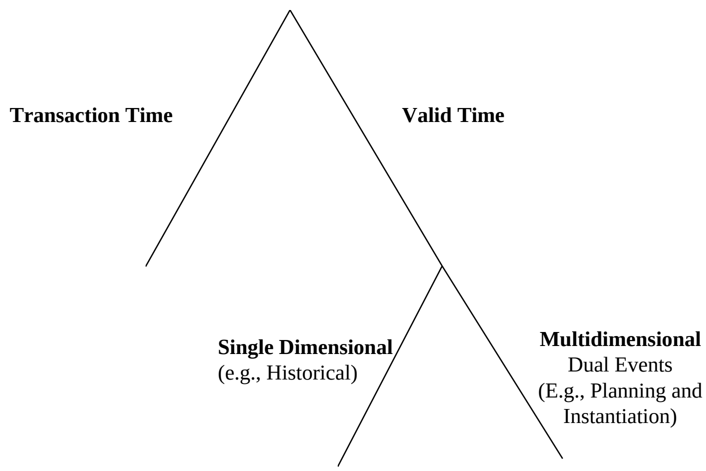
Valid time was developed before transaction time (McKenzie and Snodgrass 1991). Valid time and transaction time are orthogonal events, but still can be used in concert with each other. Distances between transaction time and valid time provide a basis for determination of control problems. For example, if there is a large "distance" between valid and transaction time, there may be reason to suggest fraud. Similarly, if transaction time is after valid time, that may also indicate fraud. Any relationship that is anomalous can be studied and used to facilitate fraud analysis.

A system that supports only valid time is called historical. A system that supports transaction time is called rollback. A system that supports both valid time and transaction time is called a temporal system. This paper proposes a temporal system, rather than a historical system or rollback system.

Single Dimensional vs. Multidimensional Valid Time

Those events designed to capture historical information, e.g., customer orders, generally need a single dimensional model of time. Historical events need measures of start and finish or equivalent. For example, "absolute time" discussed by Hollander et al. (1996) above, is "historical" valid time.

However, in some cases, there is the need for multidimensional valid time for events. When we begin to integrate planning capabilities, additional valid time information becomes important. For example, we might be interested in when a resource, such as a truck, is scheduled for use and when it actually was used, requiring multiple dual dimensions. Valid time, for single and multidimensional events, and transaction time are summarized in figure 3.



Transaction Time vs. Valid Time

Figure 3

V. Transaction Time and Valid Time for REA

Transaction time and valid time, can be embedded in resources, events, agents and locations.

Transaction Time for Resources, Events, Agents and Locations

Transaction time can be used to meet the control and performance evaluation requirements. Worker productivity might be measured based on average time per event recorded or resource (agent or location) information updated. Further, the existence of fraud might be determined based on transaction time information. For example, if the start of an event is before transaction time or the distance between transaction time and the start of an event is substantial then that could indicate fraudulent activity. Accordingly, transaction time can provide substantial control information. Thus, transaction time, such as start transaction time and end transaction time, or equivalent can be captured for each resource, event, agent and location.

Valid Time Model for Resources, Agents and Locations

In order to facilitate the existence of virtual organizations, firms need to be able to access resource availability time information. Certain resources (agents or locations) are only available for usage at particular times. Availability time must reflect issues such as contractual requirements or limitations. For example, most of the work force is available roughly from 8:00 am to 5:00 pm, Monday through Friday, excluding holidays and vacation time. Availability time (time that is theoretically available) can be captured by exploiting a periodic model of time based on, e.g., contiguous hours and days of the week <8, 5, Monday, Friday>. However, the particular model used may employ sets for some information, rather than contiguous information. For example, days of the week that are worked may not be contiguous. As a result, in order to capture time set information, sets of days may be captured, e.g., (Monday, Tuesday, Thursday, Friday, Sunday).

Single Dimension Valid Time

For events designed to capture historical information, a single dimensional model of time is appropriate, as seen in previous research, as noted above.

Multidimensional Valid Time Planning for Events

Planning is required both intra firm for enterprises and inter firm for virtual organizations and other activities. In order to capture time related to plan and its instantiation, a multidimensional model of time would be required.

Intra Firm Planning. Time requirements necessary to facilitate intra firm planning vary across events and industries. However, in any case planning requires the capability to reserve assets for use to implement the plan.

(a) Reserve Time. Enterprise planning requires the ability to "reserve" resources, agents or locations. Examples of availability used in enterprise systems are the events of making inventory "available to promise" to clients and "reserve materials for planned use" (Whang et al. 1995, p. 26). In order to reserve resources, agents or locations, a reservation event must occur that specifies the time over which the reservation would take place and the length of time before the reservation would expire.

(b) Reservation Actuality Time. Reservation actuality time is the instantiation of the reservation time. This event is dual to the reserve time event, and would include, for example, actual start and actual finish times or equivalent.

Interfirm Planning. Plans can be built around other firms' schedules for resources, agents or locations. For example, a train may be scheduled to arrive at a particular time to pick up goods. As a result, our firm needs to plan around an externally controlled event and capture information about the quality of such services. A firm plans use around that schedule, thus, the relationship between that schedule and its instantiation are important information that can be used to help choose firms to work with and evaluate quality of service.

(a) Scheduled Departure Time. The schedule of an externally owned asset, such as a train, is an example of a "schedule departure time," although the same concept can be used for other types of assets. Given a schedule of departure times, a firm can plan around the schedule or take a proactive approach at trying to find a schedule that meets its needs. A scheduled planning time model would capture at least the expected arrival time and expected departure time, or equivalent information.

(b) Actual Departure Time. As noted by McKenzie and Snodgrass (1991), in some instances the relationship between scheduled and actual times may be of interest. For example, in transportation, scheduled departure of a truck or train or car, often must be compared to actual departure time. As a result, actual departure time is a critical dimension of time, and is dual to scheduled departure time. A schedule planning departure time might include actual arrival and departure of the train, or equivalent information.

Planned Time vs. Historical Time

Historical time represents when an event has occurred and how long it took. Historic time does not cancel. In particular, for control purposes, systems that capture accounting events do not cancel those events.

However, planned events can be cancelled, and often are cancelled. As a result, planned events (both internal and integrating) need to capture cancellation information. Accordingly, in plan time events, typically there will be need for a field indicating whether an event has been cancelled. The cancellation event can also capture time-based information.

VI. Implementation

Throughout, duality drives the multidimensional valid time models for two reasons. First, each tuple must have both a unique legal and transaction time. Second, for every planned event there is a dual actuality, otherwise the plan is not implemented. Basically, the same model is employed for both intra and inter firm events.

General Dual Model for Multidimensional Time Stamps

For each pair of planned and actual instantiated time, the following general template will allow capture of all the necessary planning and instantiation information, while allowing each tuple to have a single transaction time. The dual nature of REA is used to capture the relationship between these sets of events.

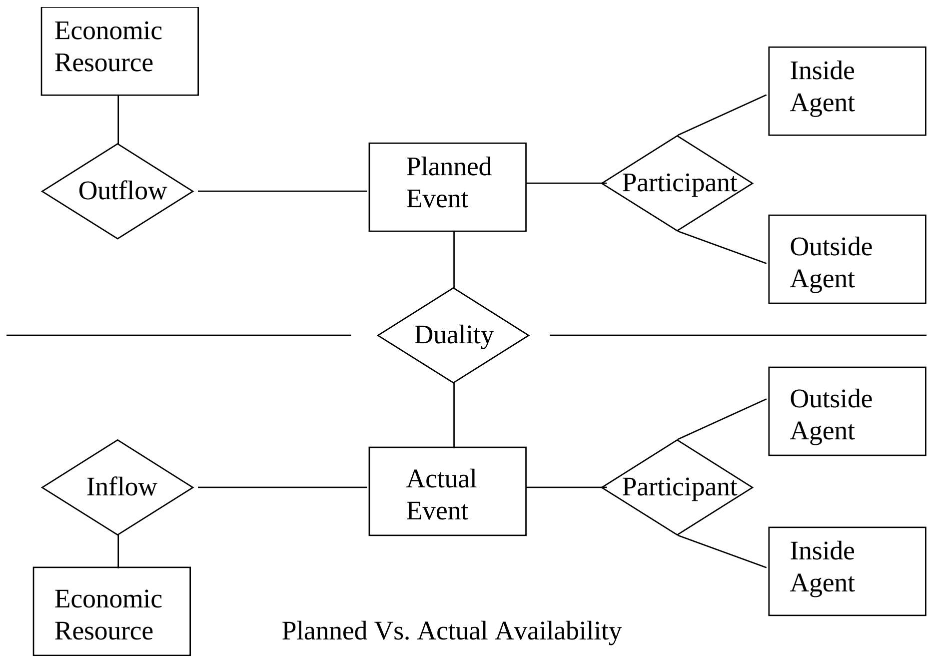


Figure 4

Data Structure

This can have implications for relational database tables or object development. Each of the planned and actual events has representations that include both transaction and valid time. Since actual and planned time transactions occur at different times, they are captured as dual events, each with their own transaction time. As a result, each tuple will have a unique time representation. Sample planned and actual time data structures are summarized in figures 5 and 6.

Sample Planned Time Event

Planned Event	Transctn Start Time	Transctn FinishTime	Planned Start Time	Planned Finish Time	Cancelled

Events Capture Both Transaction and Valid (Planned Start and Finish Time)
and allow for capture of cancellation information

Planned Time Event

Figure 5

Sample Instantiated Planned Time Event

Planned Event	Transctn Start Time	Transctn Finish Time	Actual Start Time	Actual Finish Time	Cancelled

Events Capture Both Transaction and Valid (Planned Start and Finish Time)
and allow for capture of cancellation information

Planned Time Event

Figure 6

VII. What Does the Model Accomplish?

This section investigates how the models meet the requirements of three different dimensions: Time, REA and Virtual Organizations.

Time Dimension

McKenzie and Snodgrass (1991, p. 51 -527) elicit a number of time representation capabilities. In addition to a number of database algebra characteristics, those tuple-based capabilities include the following, each of which is satisfied with our dual REA model of transaction and legal (planned and actual) time.

- Transaction time stamps tuples (tuples get time stamped). Otherwise, different attributes may not be valid when other tuple attributes are valid.

  Resources, events, agents and locations were given unique valid time and transaction time stamps.

- Multidimensional valid model time is tuple-based (otherwise there may be problems maintaining consistency for a tuple.

  The model specifies planned and actual times as events that can be attached to a tuple, e.g., as an embedded key.

- Time is supportable as a snapshot, rollback, historical or temporal relationship.

  Since the model captures valid time and transaction time, all four relationships can be supported.

- Valid time and transaction time are represented separately.

  Valid time and transaction time were captured separately for each component of resources, events, agents and locations.

- Time has a unique representation.

  The conceptual models used to represent time are unique

- Model does not require null attribute values.

  Missing or unknown information does not need to be recorded. However, missing information can limit the quality of the queries aimed at studying, e.g., efficiency.

- Model supports static attributes.

  If only a static view of the world is desired, then the planning time and instantiation events need not be used.

- Multidimensional time stamps are supported.

  Planning-based events often require multiple dimensions: Schedules, compared to instantiations and plans as compared to instantiations. Using REA duality, multidimensional time valid time stamps are supported.

REA Dimension

Models of time were proposed for resources, agents and locations, and also for events. Within events, time models were differentiated by single dimensional (e.g., historical) and multidimensional (e.g., planning and instantiation of plans) valid time models. Inter and intra firm events had similar dual structures. Generally, the information facilitated determination of availability of an asset (resource, agent or location), the scheduling of those assets and the actual use of those assets in the plan.

Virtual Organization Dimension

Two different aspects associated with virtual organization interaction were addressed. First, virtual organizations need to be able to know when sharable resources, agents and locations are available. As a result, time availability was proposed for each of resources, agents and locations. Second, virtual organizations need to know scheduled events of the virtual organization. This knowledge can be used to see which firms stay on schedule and which are too busy for additional work. As a result, schedule event information, and its instantiation were captured as events.

VIII. Summary, Extensions and Contributions

This final section summarizes the paper. In addition, it also briefly discusses some extensions and contributions.

Summary

This paper has suggested additional models of time based on transaction and valid time for each of resources, events, agents and locations. These time models were designed to provide

- control and performance monitoring capabilities, required in contemporary computer-based systems,
- resource, agent and location availability information, necessary for virtual organizations and
- capture planning event and instantiation information needed for intra and inter firm planning.

Extensions

There can be a wide range of time-based issues that can be addressed, many of which are industry specific, and beyond the scope of this paper. For example, work rules limit scheduling of pilots in airline industry applications, as a function of flight hours over some period of time. Active databases also could be used to ensure that work rule constraints are met.

McKenzie and Snodgrass (1991) note that there is no "perfect" time algebra, since there are conflicting and incompatible criteria for any time algebra. In particular, tuple time stamped data and attribute time stamped data are inconsistent. If tuples are individually stamped then attributes do not have their own time stamps. This paper is focused on tuples, however, the approach could be extended to an attribute-based approach.

Contributions

REA researchers to-date have focused primarily on the capture of a single dimension of time for events, historical. Little attention has been given to transaction time within the context of REA. Further, researchers primarily have been concerned with models of time for events, and not resources, agents or locations.

This paper extended the time model to valid time structures beyond historical data to include planning and instantiation of those plans. An REA dual model was developed to capture the relationship between plan time and plan instantiation time. In addition, transaction time was associated with resources, events, agents and locations. Finally, an historical model of time was presented to capture resource, agent and location availability.

References

Bubenko, J., “The Temporal Dimension in Information Modeling,” **Architectures and Models in Database Management Systems,** North Holland, The Netherlands, 1977, pp. 93-118.

Chen, P. “The Entity - Relationship Model-- Toward a Unified View of Data,” **ACM Transactions on Database Systems**, March 1976, pp. 9-36.

Dey, D., Barron, M., and Storey, V., “A conceptual model for the logical design of temporal databases,” **Decision Support Systems**, Volume 15, 1995, pp. 305-321.

Dunn, C. and McCarthy, W., “The REA Accounting Model: Intellectual Heritage and Prospects for Progress,” **Journal of Information Systems**, Spring 1997, pp. 31-51.

Gal, G. and McCarthy, W., "Operation of a Relational Accounting System," **Advances in Accounting**, Volume 3, pp. 83-112.

Goldman, S., Nagel, R., and Preis, K., **Agile Competitors and Virtual Organizations**, Van Nostrand Reinhold, New York, 1995.

Hollander, A., Denna, E. and O. Cherrington, **Accounting, Information Technology and Business Solutions**, Irwin, Chicago, 1996.

Hollander, A., Denna, E. and O. Cherrington, **Accounting, Information Technology and Business Solutions**, Irwin McGraw-Hill, Chicago, 2000.

McCarthy, W., “An Entity – Relationship view of Accounting Models,” **Accounting Review**, October 1979, pp. 667-686.

McCarthy, W., “The REA Accounting Model: A Generalized Framework for Accounting Systems Shared Data Environment,” **Accounting Review**, July 1982, pp. 554-577.

McKenzie, L., and Snodgrass, R., “Evaluation of Relational Algebras Incorporating the Time Dimension in Databases,” **ACM Computing Surveys**, Volume 23, December 1991, pp.

501-543.

O'Leary, D., "REAL-D: A Schema for Data Warehouses," **Journal of Information Systems**, Volume 13, Spring 1999, Number 1, pp. 49-62.

Snodgrass, R., **Developing Time Oriented Database Applications in SQL,** Morgan Kaufmann, July 1999.

Snodgrass, R., Bohlen, M., Jensen, C., and Steiner, A., “Adding Transaction Time to SQL/Temporal,” November 1996, ANSI X3H2-96-502r2, ftp.cs.arizona.edu/tsql/tsql2/sql/mad146.pdf

Snodgrass, R., Bohlen, M., Jensen, C., and Steiner, A., “Adding Valid Time to SQL/Temporal,” November 1996, ANSI X3H2-96-501r2 ftp.cs.arizona.edu/tsql/tsql2/sql/mad147.pdf

Tenor, W., "Expert Systems for Computer Security," **Expert Systems Review**, Volume 1, Number 2, pp. 3-6.

Whang, S., Gilland, W., and Lee, W., “Information Flows in Manufacturing Under SAP R/3,” 1995, Stanford University Graduate School of Business.