A transaction-oriented architecture for structuring unstructured information in enterprise applications

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Chapter 16
A Transaction-Oriented Architecture for Structuring Unstructured Information in Enterprise Applications

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ABSTRACT

As 80-85% of all corporate information remains unstructured, outside of the processing scope of enterprise systems, many enterprises rely on Information Systems that cause them to risk transactions that are based on lack of information (errors of omission) or misleading information (errors of commission). To address this concern, the fundamental business concept of monetary transactions is extended to include qualitative business concepts. A Transaction Concept (TC) is accordingly identified that provides a structure for these unstructured but vital aspects of business transactions. Based on REA (Resources, Events, Agents) and modelled using Conceptual Graphs (CGs) and Formal Concept Analysis (FCA), the TC provides businesses with a more balanced view of the transactions they engage in and a means of discovering new transactions that they might have otherwise missed. A simple example is provided that illustrates this integration and reveals a key missing element. This example is supported by reference to a wide range of case studies and application areas that demonstrate the added value of the TC. The TC is then advanced into a Transaction-Oriented Architecture (TOA). The TOA provides the framework by which an enterprise's business processes are orchestrated according to the TC. TOA thus brings Service-Oriented Architecture (SOA) and the productivity of enterprise applications to the height of the real, transactional world that enterprises actually operate in.

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INTRODUCTION

The major benefit of adopting a structured model of a problem is so that such models draw out all the relevant parameters of a problem, from which its dynamics can be better understood and its possible solutions investigated more meaningfully. Contrast this with a written or spoken text discussion (such as word-processor document or emails), where ambiguities and obfuscations can occur easily. This 'natural language' interpretation of problems may be the most flexible and easily followed, but without at least a basis in some structured form it can be dangerously wrong. Yet it is claimed that 80-85% of all corporate information remains unstructured (Seidman & Ritsko, 2004). It is thus worryingly easy to omit or misinterpret the salient issues of a given business problem. Consequently, enterprises miss valuable business opportunities. Or they undertake transactions that they later regret, as recent financial turmoil have only too clearly shown (Borio, 2008; Kramer, 2008).

The accounting discipline provides sophisticated models for capturing the problem dynamics of economic activity in a structured way (Zimmerman, 2006). Accounting recognises the concern that "if it can't be measured then it can't be evaluated, and if it can't be measured it can't be managed". Accounting thereby offers the enterprise the tools it needs to capture and analyse otherwise unstructured data. Whilst we shall see that accounting too permits enterprises to omit or misinterpret the salient issues of a business problem, it offers a useful vehicle by which we may be able to capture unstructured information in a principled way – namely through the notion of transactions.

STRUCTURE THROUGH TRANSACTIONS

Previous work has identified how transactions might provide structure to the unstructured (Hill, Polovina, & Shadija, 2006; Polovina & Hill, 2005; Polovina & Hill, 2009). Enterprise Information Systems (EIS) echo this underpinning concept (Groenewegen, 1993). These systems model the enterprise and process its business activity based on the concept of a transaction. Such transactions may involve databases, accounting, financial/asset management, operational (e.g. payroll and pension), enterprise resource planning (ERP), decision support systems or others. These systems may only capture certain transactional elements of the domain that they represent. Accordingly, like accounting, these systems can omit or misinterpret the salient issues by making 'errors of omission or commission' (i.e. omit or misinterpret the salient issues of a business problem as we have described).

In Accounting

In order to provide a structure for modelling transactions the traditional model of accountancy, the bookkeeping model, was developed in the Middle Ages (Lee, 1986). The principle behind this model is economic scarcity. In other words for every benefit a sacrifice has to be made. For example, the benefit of a business owning its office is sacrificing £1,000,000 that could be employed elsewhere; a book prepared by its author researching a new exciting area in semantic understanding may have involved that author deciding against many complex yet important alternatives, such as the costs of not participating in his or her growing family. These 'transactions' occur because the decision-maker makes an intuitive (hence unstructured) 'value judgement' that the benefits outweigh the costs. The bookkeeping model is simple but rigorous. Fundamentally, instead of recording one amount per transaction it records two: A 'debit' and a 'credit'. Moreover these

amounts are complementary to one another; hence they 'balance' against each other. An accounting 'balance sheet' is merely the aggregate of all these debits and credits. The rigorousness derives from this principled 'double entry' structure so that each benefit is accounted for by a cost and vice versa. Hence every gain is matched to a sacrifice.

Issues in Accounting Transactions

However, on deeper investigation the double entry bookkeeping model is unlikely to capture key aspects of the transactions. Say the business in the example above decides to sell its office. This transaction can be recorded easily by the elementary bookkeeping entries "DEBIT Cash £1,000,000, CREDIT Fixed Assets £1,000,000". The author preparing the book is simply too qualitative to be recorded by the bookkeeping model yet the author may want to know clearly about *all* the actual costs and benefits of such a transaction. This neglect on the part of the bookkeeping model is elaborated below.

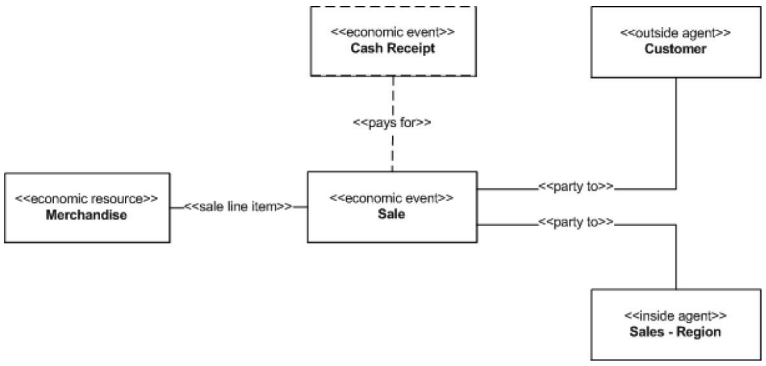
The threshold where the bookkeeping model may break down is perhaps lower than may be thought. Reconsidering the first example about the office, the value of selling the current office may be the purchase of cheaper offices for £1,000,000. The double entry would be "DEBIT Fixed Assets £1,000,000, CREDIT Cash £1,000,000". Now say, by spending the remaining £1,000,000 elsewhere, the business generates revenue of £1,100,000. On aggregate in the balance sheet the business's money worth then increases by £100,000 (Represented by the double entry "CREDIT Profit and Loss Account £100,000, DEBIT Assets £100,000"). However if the value of the current office is retaining key employees through a comfortable work environment then, as in the author example above, the bookkeeping model is inappropriate. Therefore the double entry bookkeeping model is easily liable to make significant *errors of omission*. Whilst this example may appear rather simplistic, it is well known that office relocations can have such dramatic adverse effects even though it 'saves money' and a whole industry has grown around this issue (Attwood, 1996).

Furthermore the bookkeeping model could mislead. Reconsidering the 'preparing the book' example the value may be viewed as the more easily quantified cost of the author ceasing to conduct consultancy work at £5,000 a week instead. This revenue would have been recorded by the bookkeeping model on an ongoing basis. However the book might bring its author the satisfaction of an enhanced reputation amongst peers. Unless this can be translated into a cash benefit the bookkeeping model would not record these judgements and thereby leave a 'loss' of £5,000. By choosing to author the book the decision-maker *qualitatively* has to justify, *against the grain of the bookkeeping model's assessment of value*, why that £5,000 each week has been forsaken even though this may the lesser value item. Therefore the double entry bookkeeping model, taken too literately, can readily lead to significant *errors of commission*. Whilst once again this appears to be an elementary example designed to illustrate the point, Claret describes a pertinent industrial scenario where the accounting system was dysfunctional to the information needs of the organisation, causing it to make the wrong decisions even though that organisation's operations director was acutely aware of the problem (Claret, 1990).

Resource Event Accounting/Agents

The REA (Resources, Events, Accounting) model recognises these familiar problems in accounting (Geerts & McCarthy, 1991; McCarthy, 1987). The 'A' in REA has since been updated to Agents i.e. REA (Resources, Events, Agents) reflecting its on-going development (Hruby, 2006). Whichever starting point we care to choose we can note that REA, unlike the bookkeeping paradigm, attempts to capture the qualitative dimensions of economic scarcity. REA captures an exchange of resources based on the resources themselves unrestrained

Figure 1. The REA model in UML



by superficial monetary measures. It drives to the heart of business transactions by recognising that "… the economic activities of an entity are a sequence of exchanges of resources - the process of giving up some resources to obtain others. Therefore, we have to not only keep track of increases and decreases in the resources that are under the control of the entity but also identify and record which resources were exchanged for which others." (Ijiri, 1967)

To achieve this, REA models are built using the following core concepts:

- *Resource* - any resource that is the subject of an exchange or transaction;
- *Event* - the activities that are required for a transaction to take place;
- *Agent* - a person, system or organisation that participates in the transaction.

Figure 1 depicts the original REA model in Hrubý's (Hruby, 2006) use of UML (www.uml.org).

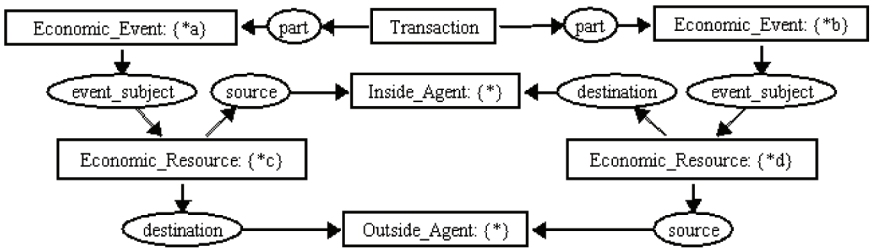
REA thus represents a powerful means of recording scarcity as more than a monetary measure. Without worrying about the significance of its 'dotted' part for now, Figure 1 reveals the fundamental links between an 'economic resource', which means some exchangeable item of value, and the parties which create the 'economic event' that causes the economic resource to be exchanged.

REA as Conceptual Graphs

In subsequent work the REA model has been represented in Sowa's Conceptual Graphs (CGs) (Polovina, 2007; Sowa & Zachman, 1992). CGs provide a powerful knowledge representation environment, whilst exhibiting the familiar object-oriented and database features of contemporary enterprise and web applications. CGs capture the nuances in natural language whilst being able to be implemented in computer software. CGs were devised by Sowa from philosophical, psychological, linguistic, and artificial intelligence foundations in a principled way (Sowa, 1984). Furthermore CGs are core to the recent ISO Common Logic standard (http://cl.tamu.edu/). CGs are attractive as they are built upon such a strong theoretical and wide-ranging base. There are industrial examples using CG such as Sonetto (Sarraf & Ellis, 2006) and Erudine (www.erudine.com/products-data-visualisation-tool). Numerous examples support the case for capturing the REA model in CG (Gerbé, Keller, & Mineau, 1998; Hill et al., 2006; Hill, 2010a; Launders, 2009).

The REA UML model of Figure 1 is thus transformed into the REA CGs model, Figure 2. This figure captures the duality in the 'dotted part' of Figure 1 referred to earlier. In other words, the 'cash receipt pays for the sale' in Figure 1 is really a shorthand to make that diagram concise. For instance 'party to' should also connect to 'cash receipt' because it is also part of the exchange.

Figure 2. The Transaction Concept



By completing REA's representation in conceptual graphs as shown by Figure 2, this duality is revealed in full.

The Transaction Concept

Transaction in this sense is thus a high-level declarative statement that conceptualises the enterprise itself rather than a number of lower-level transactions that support its business processes. This Transaction Concept (TC) restates the enterprise's mission statement, but in a balanced way that shows what an enterprise is willing to sacrifice ('pay') to satisfy the desires in its mission statement. It therefore sets the value of the mission statement, which is essentially qualitative in nature. Many enterprises, such as charities, universities, government, do not seek to maximise their profit in purely monetary ways. Even many outwardly profit-oriented enterprises present their mission statements in qualitative ways (e.g. quality of service, duty to all stakeholders, society, and reputation).

Figure 2 is the generic TC. The TC has also been referred to as the Transaction Model (TM) e.g. (Polovina & Hill, 2009). Both sides of duality are shown in the TC by linking the economic events to the same transaction. This, like REA, gives the same notion of balance as in the double entry bookkeeping model. As such it continues REA's capture of the essence of accounting by providing abstract constructs to model organisational transactions, including the bookkeeping notion of duality *and* drawing on the power of CGs. The duality relationship permits two economic events to be represented as a mirror-image exchange of resources, thereby forming the basis of a transaction. As one value describes the benefit in the transaction, the other value depicts what had to be sacrificed for that benefit.

Like REA, the TC comprises two *Economic Event* concepts, denoted by {*a} and {*b}. The transaction is complete when both economic events balance, which indicates that {*a} always opposes {*b}, representing debits and credits. The 'event subject' of these events are related to the two *Economic Resource* concepts, {*c} and {*d}, each having independent source and destination agents. Note that here we have refined the 'party-to' relations in the original REA model to 'source' and 'destination' relations to describe the actual movement of the resources. The *Inside Agent* and *Outside Agent* refer to the parties involved with the transaction. The Inside and Outside prefix denotes the relative perspective of the transaction for each party. The braces '{}' denote plurality, indicating that each concept can represent a number of aggregated resources, events or agents.

The TC allows us to support the computation of these qualitative concepts and capture hitherto hidden transactions that would otherwise be a lost opportunity for an enterprise. Put simply, the TC has the ability to structure the previously unstructured aspect of transactions. As such it structures more of that remaining 80-85% of corporate information that we identified at the beginning of this discussion in a computer-based organisational memory. Accepting that the TC

is a model of the enterprise, it offers a common basis by which an enterprise's knowledge of itself and its environment can be accessed and manipulated across all its divergently encoded data, information and knowledge bases according to this fundamental concept.

This generic TC with its generic concepts of 'Economic Resource', 'Economic Event' and 'Inside/Outside Agent' may be appropriately specialised to any quantitative or qualitative concept describing more specific items of interest. In Figure 1 the specialisations of 'Merchandise', 'Cash Receipt', 'Sale', 'Sales – Region' and 'Customer' were illustrated. The simple but illuminating case study that now follows reveals a more expressive use of the TC.

A SIMPLE EXAMPLE: P-H UNIVERSITY

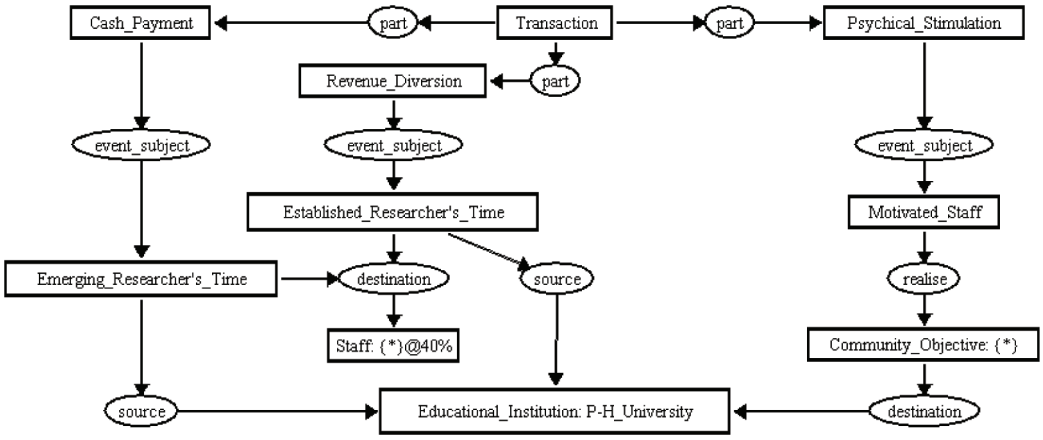
P-H University is a fictional higher education institution that has a student population of 15,000 and an annual turnover of £15m (15,000,000 British pounds). It specialises in technological subjects, with centres of excellence in certain areas. Due to the uncertain impact arising from reduced government financial support, students' anxieties in paying higher fees, increased staff and equipment costs, and an increasingly competitive higher educational market it has had a difficult year and is expected to remain so for the next three years. Indeed this year the university will make a loss of £1m.

The university's staff members are concerned about keeping their jobs, not helped by the equivocal statements given by management who are in turn pressed by the financial statements that paint a grim picture. Consultants to the university have advised that it will revert to profit, as there is an increasing trend by industry to recruit technological graduates, as well as a significant increase in interest by schoolchildren in technology after a number of successful initiatives by government and industry. The university's management are nonetheless concerned that the university will not survive until then, which they view as uncertain anyway, and has suspended all staff development and is seriously considering applying the same to the research budget for emerging researchers who do not yet generate income. The university is beginning to lose key staff who simply choose to leave, and risks losing credibility amongst its community and its profile in higher education overall. But by saving these costs a net surplus of £1m can instead be made, further increased by the salaries saved (allowing for pay-offs such as redundancy or other associated costs) of those staff leaving.

Many of P-H's staff are research active. This means they pride themselves on the quality of their research. 20% of the staff generate 80% of the research output. They bring in a substantial amount of research income that contributes £7m to the bottom line. A further 40% are emerging researchers contributing the remaining 20% of the research output but little that is income generating presently. It is this group that are most affected by the proposed research budget cut and although most of these staff are resigned to this fate, it will have a significantly adverse impact on their motivation. This will have an effect on P-H that presently cannot be calculated but is worryingly adverse. The other 40% of staff are interested in teaching only and do not contribute to research, but are already de-motivated by the loss of staff development. As many of them aspire to be research active, the loss of psychical enjoyment offered by this career path, like those already engaged in research is incalculable. Would the loss of its staff's psychical stimulation reflected in key staff leaving and the rest being demotivated, undermine the very purpose of the university, let alone its return to profit?

The university's Director of Research and representatives of the research staff meet to decide what the best course of action should be. They have distilled the situation as that captured by Figure 3,

Figure 3. The TC for P-H University



which is the specific TC for this enterprise. The basis of this CG was Figure 2, the generic TC we have already encountered.

From P-H University's TC we can observe the following:

- The transaction reveals its validity through the costs being outweighed by the benefits of the university achieving its community objectives by undertaking this transaction. As we know the *{*}* in *Community Objective* above denotes a plural, thus stating that we are referring to community objective*s*.
- The balancing of these debits and credits denotes the exchange of resources but over and above the simple monetary aspects, thus in a conventional system this could not be captured leading to errors of omission or commission.
- The TC shows that *Cash Payment* and *Revenue Diversion* versus *Psychical Stimulation* are the two complementary sets of economic events that trigger the transaction. In CG theory they are hierarchical subtypes of *Economic Event*. The terms subtype (and supertype) are analogous to subclass (and superclass) in Object-Orientation (OO) (Fowler, 2004).
- The *event subject* relations (i.e. the states altered by the economic events) highlight the salient time and staff motivation resources (being subtypes of *Economic Resource*).
- The *source* and *destination* relations (i.e. providers and recipients) of the resources are the agents in the transaction. The subtype of *Inside Agent* in this scenario being the educational institution, with the *Outside Agent* being the staff involved as its corresponding subtype.
- The *{*}@40%* once again describes a plural of staff, but in particular the 40% who are the emerging researchers.
- P-H University is shown as a referent of *Educational Institution* (a subtype of *Inside Agent*), thus denoting it as a particular instance of the educational institution type. This corresponds to an object of a class in OO, or the value of a field in a database (Connolly, 2005; Fowler, 2004).

The meeting thus has the information presented in a structured way that enables them to recommend that the 'top 20%' are allowed to divert some of their revenue generating activities (hence the term 'revenue diversion') to mentor the other 'up-and-coming 40%'. This 40% in

turn has managed to retain a research budget, which the director knows that the university's governing board will ratify. The top 20% have the research income generating activities from which they can sustain their existence. The meeting agrees that this provides the most conducive environment to motivate the staff (who are thus more appreciative of the difficult environment), sustain the university in the present difficult climate and grow it in the future according to its community objectives. The university will show a net loss of £0.5m (500,000 British pounds) but this is now considered the optimal worthwhile investment for achieving its community objectives whilst retaining its sound financial management. Through the TC we have overcome the need to rely on unstructured brute-force judgements or too-narrowly structured accounting measures that, unlike the TC, do not accord with the intuitive purpose of P-H University.

Missing Agent?

Whilst the P-H case study makes a number of assumptions for the sake of simplicity of this illustration, a careful examination of even this simplified example reveals that P-H University's TC is missing one key aspect. If we look again at *Community Objective* in this TC (Figure 3), we see that it lacks a source, and in the generic TC (Figure 2) every economic resource has a source and a destination. It is evident that this requirement is needed as part of balancing this transaction. Thus we have captured a potential error of omission – there is a stakeholder in our transaction that we have not explicated! Who might this 'new' outside agent be? It might be argued that this agent may not need to be explicated as it is immaterial; it's likely however that given P-H University's emphasis on satisfying its community objectives it would be key to explicate who is supplying this economic resource (being its supertype) that P-H is enjoying as a destination. It forces P-H University to consider its TC and bring this agent into it. The meeting decides that agent it is simply *Community*, reflecting the role that the community plays in P-H University's transactions. It would not have been captured in its existing (accounting or otherwise-based) information system, and left implicit in any natural language description, but it is in the structure of the TC and demonstrates another value of this approach. Figure 4 demonstrates the correctly balanced TC.

CASE STUDIES

The following experiences demonstrate the validity of the TC across a variety of domains and application areas, highlighting its general applicability:

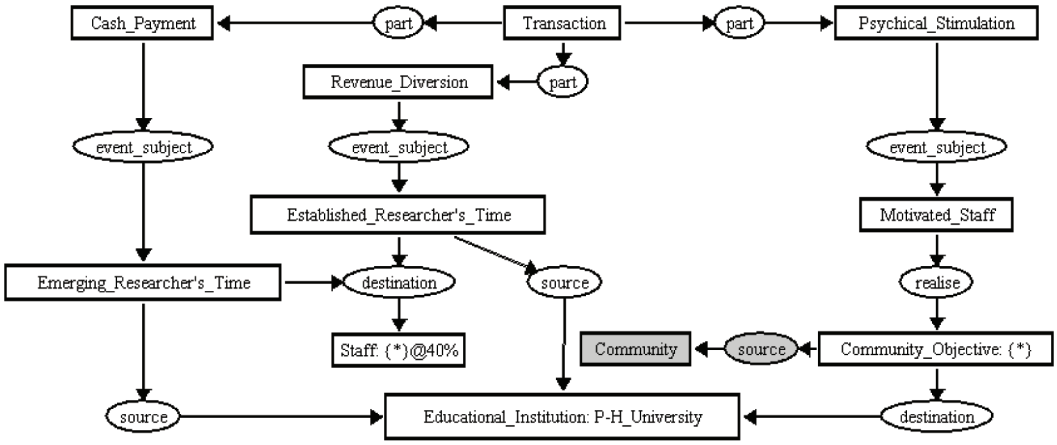
Community Healthcare

A TC was identified and explored for the complex realm of home-based community healthcare services to frail and disabled people. This domain provides a complex set of challenges for UK Local Authority Managers. Defining the agents was an involved process and there was a continual temptation to introduce redundant resources, thus contributing to high levels of cost (errors of commission). The TC was able to identify the relevant agents in a hierarchical way, and identify a new *Purchase Agent* role that had hitherto prevented progress on this work (error of omission) (Hill et al., 2006; Hill, 2006).

Emergency Healthcare

The provision and management of emergency care consumes considerable economic resources, which must be balanced against the potential increase in lives lost. One of the challenges of this domain is to identify the key performance indicators (Key PIs, or KPIs) that have a direct influence upon the monetary balance sheet, in order that they can be managed appropriately

Figure 4. The balanced TC for P-H University



without the PI measures themselves losing sight of the economic resources they are meant to measure (e.g. an unacceptable loss of lives for saving money in hard-pressed budgets). In this case the TC identified problematic qualitative concepts and enabled measures to be derived to simplify the management of these difficult issues. As such, the PIs for qualitative measures became indexes rather than the objects (economic resources) in themselves thus avoiding errors of commission (Hill et al., 2006).

Learning Environments

Mobile learning (or m-learning) presents new opportunities for learners to interact with materials using their smart phones or personal digital assistants. Analysis with the TC highlighted how this particular mode of learning raised the tensions between study-time, employment and leisure time that typical m-learners experience. As such the TC enabled learners to make an informed judgement about the costs (e.g. time sacrificed) and rewards (e.g. psychic or career benefits of qualification) in place of an ill-considered surface level desire that leads to their dropping out and wasting their energies (errors of omission and commission) (Hill, 2010a).

Early Requirements Elicitation

The combination of a rich, lucid modelling notation, foundations in formal logic through CGs and the TC has been adopted as a means of capturing and expressing ontologies at a very early stage of preliminary requirements gathering. Since the TC requires concepts to be specified, this approach also serves to identify types and their associated hierarchical relationships, thus forming the ontological basis for a domain such as those applied to above. This approach is referred to as Transaction Agent Modelling (TrAM) as a pre-early (or 'embryonic') requirements technique for multi-agent systems and the enterprise applications that can be built upon them (Hill et al., 2006; Hill, 2007).

Enterprise Architectures

The above early requirements elicitation work is being extended in the sphere of enterprise architectures, which comprise of complex transactional Information Systems that perform repetitive and bespoke business transactions to meet business goals. Contemporary enterprise architecture frameworks such as TOGAF (www.opengroup.org/togaf) and Zachman (www.zifa.com) have been widely adopted to organise design thinking about the architectural components as well as to

provide a description of architecture artefacts. Like these frameworks, the TC is core to enterprise architecture, The TC and TrAM is therefore being related with these existing enterprise architecture frameworks to explore the value-add that the TC brings to these frameworks (Launders, Polovina, & Hill, 2010; Sowa & Zachman, 1992). Allied to this work is the Open Semantic Enterprise Architecture (OpenSEA), bringing the previously referred-to ISO Common Logic (Bridges & Polovina, 2010) through CGs into these frameworks (Bridges & Polovina, 2010).

Multi-Agent Systems

An initial implementation of TrAM as a multi-agent system (MAS) now exists. In this implementation, enterprise agents take advantage of new scenarios by understanding the ontologies of other enterprises. Coupled with the belief, desire and intention (BDI) model, the TC is used as part of an agent's model for reasoning on a particular course of action. The work shows how the TC can be implemented using CGs and MAS software tools such as Amine, Jason and JADE (Hill, 2010b).

Research-Informed Learning and Teaching

Given the issues discussed thus far, it is not surprising that learning about the designing of robust, expressive software for the enterprise is a perennial challenge for students too. The TC been used for learning, teaching and assessment (LTA) to enable students to make tangible links between enterprise architectures and the needs of robust enterprise applications that reflect the issues that the TC addresses. Using a number of case studies that relate to healthcare, financial services and manufacturing, the TC has enabled learners to consider enterprise architectures that focus on the business rather than just the technology. At the outset it forces them to consider the 80-85% of unstructured information as well as the 15-20% that they see as the being the total problem with the serious levels of errors of omission and commission that can entail. The TC drives them to consider use cases for enterprise applications at the kite (business) level rather than the sea (system) level view (Fowler, 2004), and that reflect the balance the stakeholders and their transactions with the enterprise e.g. like the P-H University case demonstrated. These 'transactional use cases' are rather unconventional compared to mainstream approaches, and together with the TC enable students to engage on a path of enquiry around the real issues in contemporary architectures for enterprise applications as we have described (Launders, Polovina, & Khazaei, 2010a, 2010b).

FORMAL CONCEPT ANALYSIS

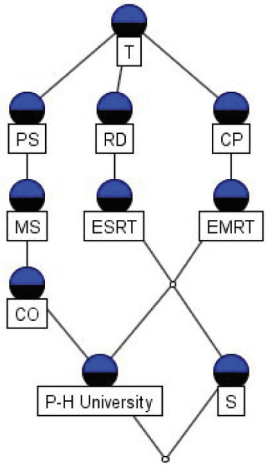
The TC can also be defined through a technique related to CGs known as Formal Concept Analysis (FCA) (Ganter, Stumme, & Wille, 2005). In FCA, formal objects and formal attributes in a domain are identified and their (un-named) binary relations are shown as crosses in what is termed in FCA as a formal context. Figure 5 shows the formal context for P-H University's original TC that was shown by Figure 3. The type labels in CGs become formal attributes in FCA and the referents in CGs become formal objects. Thus *Educational Institution* becomes a formal attribute and *P-H University* becomes a formal object. For anonymous cases (i.e. where the referent is not shown), a token is used to represent this instance, e.g. in Figure 5, *CP* is an instance of *Cash Payment*.

Figure 6 shows the concept lattice that results from the P-H University formal context. In FCA, the concept lattice depicts the hierarchy of formal objects in the context. The hierarchy can be found in the context, but it is more visible in the lattice. For example, it is clear that the transaction, *T*, is at the top of the hierarchy and that there is a hierarchical order in the object instances *T*, *PS*, *MS*,

Figure 5. Formal Context of P-H University scenario

	Cash Pay...	Emerging ...	Staff	Transaction	Revenue D...	Establishe...	Education...	Physical St...	Motivated ...	Communit...
CP	X			X						
EMRT	X	X		X						
S	X	X	X	X	X	X				
T				X						
RD				X	X					
ESRT				X	X	X				
P-H University	X	X		X	X	X	X	X	X	X
PS				X				X		
MS				X				X	X	
CO				X				X	X	X

Figure 6. The P-H University scenario concept lattice



CO and *P-H University* that depicts the dependency between such objects in the TM.

By incorporating the TC's relations into the formal attributes, shown by Figure 7, it becomes possible to see the complete TC hierarchy in the corresponding concept lattice, Figure 8.

Looking at the lattice, it is clear that emerging and established researchers are conceptually similar, having the same source and destination and only differing in their instantiation; one by a revenue diversion and the other by a cash payment. It is also again clear that CO (Community Objective) does not have a source. The obvious source would be the community. Adding this to the formal context results in the revised, now balanced TC shown in Figure 9.

An interesting natural 'layering' of concepts in the lattice is apparent, with event subjects forming an upper layer and sources and destinations forming a lower layer. The lattice provides an intuitive and easily readable representation of the CG. In figures 6 and 7, a further piece of information is given by the size of the node: the larger the node the more objects are reachable from that node. So, for example, *PS event subject* involves more objects than *RD event subject*.

Unlike the CGs that were drawn by hand (using in our case CharGer, http://sourceforge.net/projects/charger/) the FCA concept lattice is machine-generated (using Concept Explorer, http://sourceforge.net/projects/conexp/). Thus FCA offers an automated vehicle by which the hand-drawn TC in CGs can be checked by the machine-drawn TC in FCA to see if it balances, as the concept lattice automatically clusters the components of the TC (resources, events, agents i.e. REA) captured by CGs. Extending this to a fully-automated scenario, as the CG is developed it is dynamically updated in the concept lattice feeding back into the CG that is in turn re-drawn by, for example, an enterprise architect for the added clarification that FCA's concept lattice offers.

TRANSACTION-ORIENTED ARCHITECTURE (TOA)

Given the evidence thus far, it is possible to foresee the emergence of a Transaction-Oriented Architecture (TOA) (Polovina & Stalker, 2010).

Figure 7. The P-H University context incorporating the relations in the TC

	CP event s...	EMRT sour...	EMRT dest...	T part	RD event s...	ESRT dest...	ESRT sour...	PS event s...	MS realise	CO destin...
CP				X						
EMRT	X			X						
S	X		X	X	X	X				
RD				X						
ESRT				X	X					
Education...	X	X		X	X		X	X	X	X
PS				X						
MS				X				X		
CO				X				X	X	

Figure 8. The P-H University lattice incorporating TM relations

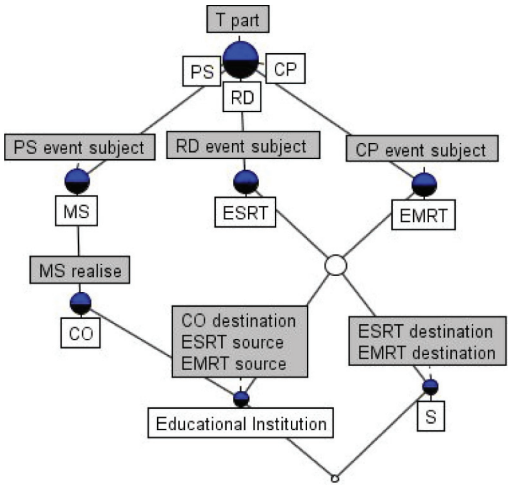
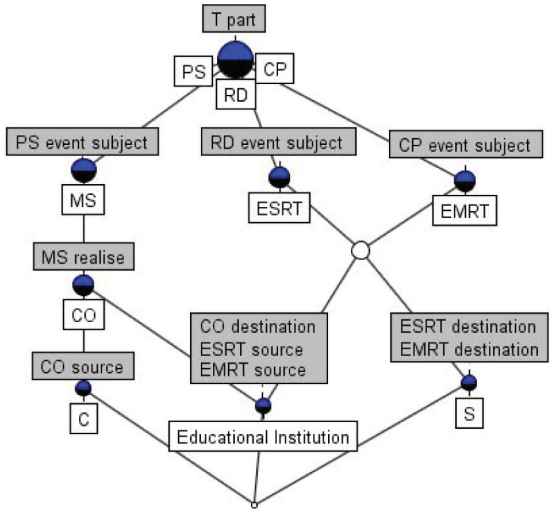


Figure 9. A balanced CG for the P-H University scenario

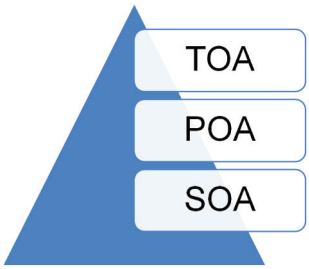


As we have seen, the TC structures the unstructured information for enterprise applications. The notion of a TOA captures the TC within an enterprise architecture that can be aligned with contemporary developments in Service-Oriented Architecture (SOA) (Sweeney, 2010). In particular, the TOA can give direction and purpose to SOA, which provides the components for an enterprise system according to business rather than technical concepts but not the overarching direction that the TC provides. Rather SOA relies on providing tools for business process experts and a governance structure as part of useful enterprise architecture frameworks such as TOGAF or Zachman referred to earlier. It can therefore be envisaged that TOA could similarly be integrated into these frameworks, hence adding the value of the TC. Process-Oriented Architecture (POA) aligns SOA towards processes rather than services, thus addressing why the services are provided (Manasco & Schurter, 2005). The TOA can also give direction and purpose to POA as processes too are subject to the overarching direction that the TC provides. The TOA thus provides the direction for SOA and POA, as illustrated by Figure 10.

CONCLUSION

In the quest to identify how enterprises may be able to structure their unstructured information to enable them to engage in the right transactions, the relevance of REA and its effectiveness through the TC was explored and demonstrated across a

Figure 10. TOA, POA and SOA



variety of domains. Using a worked example it was shown how the TC could most usefully be expressed in CG and FCA. The TC was then advanced into the TOA, setting the scene for its integration with SOA and POA in meaningful enterprise architectures.

Enterprise applications built upon the TOA would discover otherwise hidden business opportunities available to an SOA-enabled business enterprise as it transacts electronically with other enterprises. TOA captures the semantics of the intrinsic transactions that symbolise the enterprise and its aims i.e. the TC. With this knowledge the TOA can automatically orchestrate the enterprise's business processes according to these key, high-level business transactions. TOA thus brings SOA and the productivity of computers to the height of the real, transactional world that enterprises actually operate in. With TOA, enterprise systems become transformed into an informed, mediating artefact for integrating an enterprise across its numeric, data, information and knowledge-based dimension and identifying its transactions with other enterprises. Whilst there is no doubt more work to be done to fully evaluate its validity, we foresee that the TOA will become an inherent part of future architectures for enterprise applications.

REFERENCES

Attwood, D. A. (1996). *The office relocation sourcebook: A guide to managing staff throughout the move. Europe*. Wiley.

Borio, C. (2008). *The financial turmoil of 2007–? A preliminary assessment and some policy considerations* (BIS Working Papers No. 251). Basel, Switzerland: Bank for International Settlements.

Bridges, S., & Polovina, S. (2010). *An OpenSEA framework using ISO24707 common logic*. Paper presented at the 2010 International Conference on Intelligent Networking and Collaborative Systems, Thessaloniki, Greece. (pp. 335-336). DOI 10.1109/INCOS.2010.92

Claret, J. (1990). Why numbers are not enough. *Accounting Technician: The Journal of the Association of Accounting Technicians UK,* (October), 24-25.

Connolly, T. M. (2005). *Database systems: A practical approach to design, implementation, and management* (Begg, C. E., Ed.). 4th ed.). Harlow, UK: Addison-Wesley.

Fowler, M. (2004). *UML distilled: A brief guide to the standard object modeling language* (3rd ed.). Boston, MA: Addison-Wesley.

Ganter, B., Stumme, G., & Wille, R. (2005). *Formal concept analysis: Foundations and applications* (Stumme, G., & Wille, R., Eds.). Berlin, Germany & Great Britain: Springer.

Geerts, G., & McCarthy, W. E. (1991). Database accounting systems. In B. Williams, & B. J. Sproul (Eds.), *Information technology perspectives in accounting: An integrated approach* (June ed., pp. 159-183). London, UK: Chapman and Hall Publishers.

Gerbé, O., Keller, R. K., & Mineau, G. W. (1998). Conceptual graphs for representing business processes in corporate memories. In M. Mugnier, & M. Chein (Eds.), *Conceptual structures: Theory, tools and applications: 6th International Conference on conceptual structures, ICCS'98, Montpellier, France, August 1998 (Proceedings)* (pp. 401-415). Heidelberg, Germany: Springer-Verlag.

Groenewegen, J. (Ed.). (1993). *Dynamics of the firm: Strategies of pricing and organisation*. Cambridge, UK: Edward Elgar Publishing Ltd.

Hill, R. (2006). Capturing and specifying multi-agent systems for the management of community healthcare. In Yoshida, H., Jain, A., Ichalkaranje, A., Jain, L. C., & Ichalkaranje, N. (Eds.), *Advanced computational intelligence paradigms in healthcare - 1, studies in computational intelligence* (48th ed., pp. 127–164). Berlin, Germany: Springer.

Hill, R. (2007). *A requirements elicitation framework for agent-oriented software engineering*. PhD thesis, Sheffield Hallam University (pp. 1-244).

Hill, R. (2010a). *Agency and the virtual campus: The TrAM approach*. Paper presented at the 2010 International Conference on Intelligent Networking and Collaborative Systems, Thessaloniki, Greece (pp. 8-15). doi:DOI 10.1109/INCOS.2010.95

Hill, R. (2010b). Conceptual structures for reasoning enterprise agents. In Croitoru, M., Ferré, S., & Lukose, D. (Eds.), *Conceptual structures: From information to intelligence* (pp. 191–194). Berlin/Heidelberg, Germany: Springer. doi:10.1007/978-3-642-14197-3_20

Hill, R., Polovina, S., & Shadija, D. (2006). Transaction agent modelling: From experts to concepts to multi-agent systems. In H. Schärfe, P. Hitzler & P. Øhrstrøm (Eds.), *Conceptual structures: Inspiration and application, lecture notes in artificial intelligence* (LNAI 4068, pp. 247-259). Heidelberg, Germany: Springer.

Hruby, P. (2006). *Model-driven design using business patterns* (1st ed.). Springer.

Ijiri, Y. (1967). *The foundations of economic accounting*. UK: Prentice Hall.

Kramer, J. (2008, 18 September 2008). Financial turmoil. Retroieved from http://uk.youtube.com/watch?v=Sanr9kx3Mq4

Launders, I. (2009). Socio-technical systems and knowledge representation. In Whitworth, B., & de Moor, A. (Eds.), *Handbook of research on socio-technical design and social networking systems* (pp. 558–574). Hershey, PA: IGI Global. doi:10.4018/9781605662640.ch037

Launders, I., Polovina, S., & Hill, R. (2010). *Semantics and pragmatics in enterprise architecture through transaction agent modelling*. Paper presented at the The 12th International Conference on Informatics and Semiotics in Organisations, Reading, UK. (pp. 285-291). Retrieved from http://www.scitepress.org/DigitalLibrary/

Launders, I., Polovina, S., & Khazaei, B. (2010a). *Case studies as simulation of industrial practice*. Paper presented at the CPLA Enquiry, Autonomy & Graduateness Conference, Sheffield Hallam University, UK (pp. 73-88). Retrieved from http://extra.shu.ac.uk/cetl/cpla/resources/CPLA_Conference_Proceedings.pdf

Launders, I., Polovina, S., & Khazaei, B. (2010b). *Learning perspectives of enterprise architectures through TrAM*. Paper presented at the First Conceptual Structures - Learning, Teaching and Assessment Workshop (CS-LTA) at the 18Th International Conference on Conceptual Structures (ICCS 2010), Kuching, Malaysia (pp. 29-41). Retrieved from http://extra.shu.ac.uk/cetl/cpla/cslta2010/publication.html

Lee, G. A. (1986). *Modern financial accounting*. UK: Van Nostrand Reinhold.

Manasco, B., & Schurter, T. (2005). POA or SOA? *ZDNet.* Retrieved March 1, 2010, from http://blogs.zdnet.com/service-oriented/index.php?p=206

McCarthy, W. E. (1987). On the future of knowledge-based accounting systems. In M. Vasarhelyi (Ed.), *The D. R. Scott memorial lecture series, University of Missouri, and published in artificial intelligence in accounting and auditing: The use of expert systems* (October ed., pp. 19-42). USA: Markus Wiener Publishing.

Polovina, S. (2007). An introduction to conceptual graphs. In U. Priss, S. Polovina & R. Hill (Eds.), *Proceedings of the 15th International Conference on Conceptual Structures (ICCS 2007): Conceptual structures: Knowledge architectures for smart applications, July 2007, Sheffield, UK* (Lecture Notes in Artificial Intelligence 4604, pp. 1-15). Berlin/Heidelberg, Germany & New York, NY: Springer.

Polovina, S., & Hill, R. (2005). Enhancing the initial requirements capture of multi-agent systems through conceptual graphs. In F. Dau, M. Mugnier & G. Stumme (Eds.), *Conceptual structures: Common semantics for sharing knowledge, lecture notes in artificial intelligence* (LNAI 3596, pp. 439-452). Heidelberg, Germany: Springer.

Polovina, S., & Hill, R. (2009). A transactions pattern for structuring unstructured corporate information in enterprise applications. *International Journal of Intelligent Information Technologies*, *5*(2), 34–47. doi:10.4018/jiit.2009040103

Polovina, S., & Stalker, I. D. (2010). *TOASTIE: Transaction-oriented architecture for structuring the totally integrated enterprise.* Paper presented at the 2010 International Conference on Intelligent Networking and Collaborative Systems, Thessaloniki, Greece. (pp. 333-334). DOI 10.1109/INCOS.2010.93

Sarraf, Q., & Ellis, G. (2006). Business rules in retail: The tesco.com story. *Business Rules Journal, 7*(6)

Seidman, D. I., & Ritsko, J. J. (2004). Preface. *IBM Systems Journal*, *43*(3), 449. doi:10.1147/sj.433.0449

Sowa, J. F. (1984). *Conceptual structures: Information processing in mind and machine*. Boston, MA: Addison-Wesley.

Sowa, J. F., & Zachman, J. A. (1992). Extending and formalizing the framework for Information Systems architecture. *IBM Systems Journal*, *31*(3), 590–616. doi:10.1147/sj.313.0590

Sweeney, R. (2010). *Achieving service-oriented architecture: Applying an enterprise architecture approach*. Hoboken, NJ: Wiley.

Zimmerman, J. L. (2006). *Accounting for decision making and control* (5th ed.). Boston, MA: McGraw-Hill Irwin.