Problem Frames Approach for e-Business Systems

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Abstract

We propose a Problem Frames approach for e-business systems that incorporates a business strategy dimension as a means of describing the e-business problem domain. To achieve this, we employ both goal modeling and the Problem Frames approach. Jackson's context diagrams, which are used to represent the business model context, are integrated with goal-models to describe the complete business strategy. As a means of simultaneously decomposing both the optative and indicative parts of a requirements problem, from an abstract business level to concrete system requirements, we leverage the paradigm of projection in both approaches while maintaining traceability to high-level business objectives. We demonstrate the feasibility of our approach via a proof-of-concept case study from the literature.

1. Introduction

An e-business system enables marketing, buying, selling, delivering, servicing, and paying for products, services, and information, primarily across nonproprietary networks, in order to link an enterprise with its current and target customers, agents, suppliers, and business partners [1]. For e-business systems, it is important that requirements analysis capture both the strategic objectives of the business, and the activities by which those objectives are achieved. One of the challenges of an organization's e-business initiative is ensuring that the e-business system in fact addresses the real-world problems the business intends to solve. This means understanding the business model, and in the context of that model, the activities through which the company intends to generate value; i.e., the business strategy [2].

While it is not usually the role of requirements engineers to design and develop business strategy, we believe that requirements engineers must at the least understand the business strategy. This is to ensure that requirements of e-business systems align with, support, and enable business strategy, as business strategy is within the bounds of the problem domain of e-business systems. To properly achieve this, it is important for the requirements engineer to have a means of representing strategic context within the requirements engineering framework. Unfortunately, few requirements engineering approaches adequately incorporate the context of business strategy or describe the activities that support the strategy.

We thus propose a requirements engineering approach for e-business systems that incorporates a business strategy dimension as a means describing the e-business problem. Our approach integrates Jackson's problem diagrams [3] with goal modeling. We employ Jackson's context diagrams and notion of projection from the real world to the *machine* to describe business model problem context. Goal-modeling techniques capture all optative properties of the system, including business goals, strategic objectives, activities and any other business or systems requirements.

The rest of this paper is organized as follows: section 2 presents the background to our work; section 3 describes our approach and shows how a Problem Frames approach and goal modeling are integrated; section 4 presents a proof-of-concept case study based on the literature describing Seven-Eleven Japan; section 5 offers some conclusions.

2. Background

In this section, we discuss previous research and describe the requirements engineering techniques we use in our approach. In section 2.1, we review previous requirements engineering research that addresses e-business issues. In section 2.2 we discuss problem frames, their background and their potential to describe and decompose complex problem contexts. In section 2.3 we discuss uses of goal modeling to refine business goals and strategy to system requirements.

2.1. E-business and RE

Most requirements engineering research that addresses e-business does so indirectly in the context of requirements for Web-based systems or Web applications development [4-7]. Web-based systems research however focuses on architectural, usability, and other design-oriented concerns rather than business aspects. Also, by virtue of being "Web-based," Web-based systems research effectively excludes issues of e-business systems that do not use the Internet for connectivity or Web browsers as user interfaces. Other research addresses issues of *value analysis* of e-commerce applications development, but neglects *requirements analysis* [8, 9]. Castro *et al.* take a different view, and present a requirements-driven systems engineering approach that considers organizational aspects in an industrial e-business project [10]; however, the organizational focus consists primarily of dependencies between organizational actors and goals rather than business strategy .

Overall, with the exception of Castro *et al.*, what little e-businesses systems requirements engineering research there is, fails to propose concrete requirements engineering approaches. Also, the methods and techniques proposed tend to focus on producing end-products of architectural and usability design or value analysis rather than system requirements. In addition, none of the research addresses issues of business strategy directly, despite its importance in requirements analysis for e-business systems.

2.2. Problem Frames

Problem Frames, as a requirements engineering approach [3], with its strong emphasis on describing and decomposing problem contexts as they exist in the real world, is potentially a powerful tool for requirements analysis of e-business systems. Most recent research on Problem Frames has focused on what one does when one has got the frame and wants to engineer from there [11-13] or on proposing variations of frames [14] or entirely new frames [15, 16]; only Cox and Phalp attempt to derive appropriate problem frames from business process models for an e-business system [17].

While problem frames serve as powerful means of linking requirements to problem context, they are somewhat weaker at relating requirements to each other when projecting from problem context towards the *machine*. This is particularly important in problem decomposition of highly complex systems, in which complex problems are projected into increasingly detailed sub-problem diagrams. The detailed description of explicit linkages (traceability) between requirements in problems and those in the projections of their sub-problems in a *progression of problems* (see [3] pp. 103-4) is missing. We thus propose the addition of goal modeling as an effective means of describing that requirements projection.

2.3. Goal Modeling, Business Objectives, and Strategy

Goal-oriented modeling techniques in requirements engineering, in contrast to the Problem Frames approach, provide a powerful mechanism for requirements projection in goal refinement. As such, goal modeling serves as a means of linking high-level strategic goals to low-level systems requirements [18]. In fact, a number of goal-oriented techniques have been proposed for modeling business goals and objectives in the context of requirements [19-23]. While this research tends to treat business goals as discrete, independent entities, other approaches assemble business goals and their sub goals into structures representing complete business strategies, and then anchor requirements to the strategy model [24, 25].

However, despite their application to modeling business goals and strategy, goal-oriented modeling techniques have a number of shortcomings. First, they tend to be deficient in describing problem context [24]. Second, goal models tend to bloat quickly, threatening manageability [26]. This is potentially a show-stopping problem in development of large e-business systems, which can be exceedingly complex. Third, as goals are inherently hierarchical, at times it is difficult to discern where a business goal is situated in the hierarchy and how it relates specifically to the business problem context. Moreover, for every business goal, there is always a discoverable super goal, and thus goal-modeling techniques require explicit upper bounding of the problem domain [3, 27].

3. Addressing the e-Business Problem

This section is organized in the following way: we present our justification for applying the Problem Frames approach to business strategy in section 3.1; then in section 3.2 we discuss both the idea of a *progression of problems* and why it is appropriate to the e-business domain as a means of expressing context; section 3.3 shows how goal modeling can represent the requirement set.

3.1. Business Strategy as Problem Diagrams

Oliver offers a working definition of *business strategy* based on a broad survey of strategy research as "the understanding of an industry structure and dynamics, determining the organization's relative position in that industry and taking action either to change the industry's structure or the organization's position to improve organizational results" [28].

This notion of strategy is not unlike that of a *problem* according to Jackson [3, 29]. The "understanding of an industry structure and dynamics," and "determining the organization's relative position in that industry" in essence means *describing the business model*. We define business model as *a macro-level model of interaction of participants in a business system describing generating of value* based on business model descriptions adapted from [1, 30].

The business model is in fact *problem context*, and represents the *indicative* part of *strategy* [3, 29]. "Taking action either to change the industry's structure or the organization's position to improve organizational results," is the organization's strategic business plan. This is the *optative* part of the *strategy* [3, 29], that describes the way in which the organization desires to change the real world. We take this as *requirements*.

We thus propose that an e-business strategy can effectively be represented as a *problem diagram*, in which the e-business system is represented as the *machine*. We recognize that an e-business system is in fact a collection of many machines working in concert, but at this level of abstraction, we represent the entire system as one *machine*, in accordance with Jackon's rule [3]. The participants in an e-business system each represent *domains of interest* [3, 29]. As noted above, the *requirements* are the *optative* part of the strategy; i.e., the objectives and activities of the firm through which it attempts to succeed in its business. We consider all optative properties of a system to be requirements, including business goals, objectives, activities, and any other business or systems requirements.

3.2. A Progression of Problems

E-business problems at the highest level of business strategy are in fact very distant from the *machine*, or what Jackson describes as "deep in the real world" [3]. To refine requirements from high-levels of abstraction down to the *machine*, the paradigm of a *progression of problems* is particularly useful (Fig. 1). The complexity of e-business systems as well as the need to align requirements with the highest levels of business strategy has in fact pushed the domain model deep into the real world.

The *domain* DA in Fig. 1 represents the *indicative* macro-level business model. *Requirement* RA represents the *optative* properties of strategy. Through analysis of DA and RA, it is possible to find a requirement RB that refers only to DB while satisfying RA [3]. DB represents the projection of DA, but at a lower level of abstraction. Through this process of analysis, problem projection, and refinement, ultimately the requirement refers just to the *machine*.

While the paradigm of a *progression of problems* serves as a powerful framework for decomposing e-business strategy down to *machine* requirements, the Problem Frames approach provides little explicit linkage between requirements at different levels of the progression. In the example above, requirement RB must satisfy requirement RA, and RC must satisfy RB, which satisfies RA, and so on. In order to ensure that system requirements are indeed in harmony with and provide support for business strategy, explicit traceability from lower level requirements to the highest level is necessary; however, while Jackson proposes analysis of DA and RA in order to find RB [3], a framework for or means of doing this is not described. Moreover, the Problem Frames approach provides no direct linkages between RA and RB.

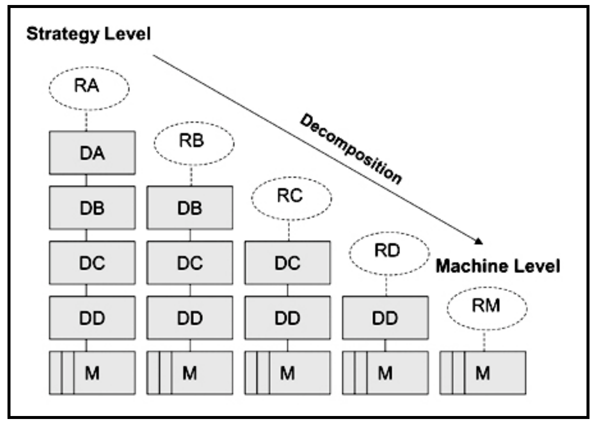

Fig. 1. A Progression of Problems (adapted from [3] p. 103)

3.3. Integrating Goal Modeling with Progression of Problems

Goal modeling is a useful technique to describe explicit linkages between lower-level requirements and higher-level objectives [18], and therefore using goal-models to represent the requirements part of the problem diagram is a possible means to trace requirements between problem diagrams in progression. Goals represent objectives that the system ought to achieve, and refer to properties that are intended to be ensured [27]. Goals are thus requirements at a higher level of abstraction. Therefore, we treat goals as *optative*, as we would a requirement, equally bounded by the problem domain [3, 29]. Goals may be formulated at different levels of abstraction, from high-level strategic concerns to low-level technical ones [18]. This is a useful tool in describing the requirements part of problem diagrams when developing e-business systems. We therefore propose the integration of goal modeling with problem frames as a means of helping ensure that the requirements are in harmony with and provide support for business strategy.

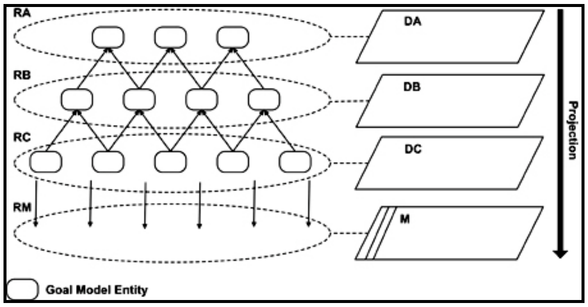

Fig. 2. Goal Model Integrated with Progression of Problems

The integration of a goal model with a progression of problems is illustrated in Fig. 2. The optative requirements at each level are described in terms of a portion of a larger goal model. The goal portions represent requirements at a level of abstraction equivalent to that of the *domain* to which they refer within the progression of problems. Each goal entity refers to specific *domains of interest* within the referred domain. The goal model enables explicit connections to requirements at adjacent levels in terms of super goals and sub goals. The sub goals are in fact projections of their super goals, and satisfaction of the sub goals guarantees satisfaction of the super goals in the same way that satisfaction of RB guarantees satisfaction of RA (Fig. 1).

Thus the goal model effectively ensures that the requirements are in harmony with and provide support for business strategy from highest-level to lowest-level requirements while enabling traceability from *machine* requirements to strategic objectives. The context diagrams in the progression of problems (DA, DB, DC, …) complement the goal model by providing problem context at various levels of abstraction with explicit linkage to requirements. Moreover, the integration of context diagrams with goal modeling also improves manageability of goal models of complex systems. The sub problems enable a decomposition of the requirements, represented as portions of the goal model, into manageable chunks, while still maintaining explicit linkages. Also, individual business goal entities are explicitly situated in the context of the problems at explicit levels of problem abstraction.

4 Proof of Concept Case Study: Seven Eleven Japan

We use a business case from literature of Seven Eleven Japan's e-business system to illustrate our problem frames approach. We take the case of Seven Eleven Japan (SEJ) from a number of sources [1, 31-34].

4.1. Overview of SEJ's Business Strategy

Seven-Eleven Japan, like its US progenitor, manages a national network of convenience stores. Unlike Seven-Eleven USA, SEJ generates value by leveraging and controlling ownership of information to optimize efficiency across a value chain with an unparalleled manner of sophistication. SEJ actually owns very few physical assets. The company positions itself in the center of a value chain that includes manufacturers, distributors, third-party logistics providers, and franchise shops, all of whom are independently-owned companies, yet all of whose objectives are maximizing throughput of products ultimately sold to franchise shop end-customers. SEJ's macro-level business model includes the participants mentioned above and their shared phenomena in terms of transactional flows of money, information, and products, based on the description of e-business models appearing in [1].

SEJ bases its strategy for competitive advantage on an extremely high level of competency at anticipating consumer purchases store-by-store, item-by-item, hour-by-hour, and then providing customers with products they want when they want them. SEJ's strategy leverages information technology to accomplish its strategic objectives. Its ownership of information enables sophisticated supply chain management to reduce inventories, lower costs, and increase sales. SEJ moves information between itself and its partner companies via an ISDN network (incidentally, SEJ's e-business strategy is *not* Internet-based, nor are its systems Web-based). To better understand customer demand, SEJ actively gathers and analyses purchasing information in real time, and correlates this with other social and environmental factors, including neighborhood demographics, planned local events like festivals, and the weather. SEJ then uses a highly acute just-in-time (JIT) delivery system to meet that demand generating remarkable value. It is these activities and their objectives that constitute the optative part of the SEJ e-business problem.

4.2. Progression of Problems of SEJ

Let us examine the progression of problems of SEJ's e-business system from the top, macro-level of business strategy down to the machine devices used in the franchise shops (see Fig. 3 below). Note that for the purposes of describing the approach we are only concerned with a particular sub-problem within Fig. 3 and that Fig. 3 describes only part of the SEJ e-business system problem. The macro-level business strategy is the top-level problem that is deepest into the world. It is here that we bound our problem, because it is here that SEJ bounds their problem.

The progression of problems consists of an indicative part, which we describe as a progression of context diagrams, and an optative part, which we describe as a goal model. Please note that the context diagrams do not describe every aspect in the requirement part of the problem diagram. They only describe the aspects that we address in this example. We represent the goal model in GRL notation, overviews of which are described in [21, 35]. We chose the GRL notation because of its expressiveness in being able to represent both abstract and non-abstract goals, tasks, and resources, which we felt would be helpful in modeling requirements for SEJ's complex e-business system. Please note that the entities in the goal model are grouped by dashed-line ellipses (RA, RB and RC in Fig. 3). The goal entities within the ellipses represent requirements referring to context diagrams in the progression at equivalent levels of abstraction (DA, DB and DC in Fig. 3). The integration of the goal model and the context diagram at each level in the progression presents a *problem diagram* for that particular level of abstraction.

We now describe this progression in finer detail. Our aim in the example presented here is to demonstrate traceability and alignment with requirements at higher-levels, deep into the real world. To understand the optative part of the business strategy we explore the goal model at its highest level (RA). SEJ's requirement is to *Stock products that customers want when they want them according to changing needs*. This meets the goals *Reduce lost opportunity/customer* and *Minimize unsold perishables* and is achievable by *Just-in-time delivery*, which in turn supports the goals of *Maximize use of limited floor space, Shorten inventory turns* and *Maintain constant freshness of perishable goods*. These requirements and goals can be met by *Development of effective decision support systems*. The scope of the requirement set can only be understood by an exploration of its context.

The corresponding context diagram (DA) shows the *machine* domain *SEJ Value Net Integrator System*. This retrieves the *Just-in-time* data it needs from the *Franchise Store* domain (interface *a*). To know what to deliver just in time (a goal in RA), the needs of the *Shop Customer* must be understood (interface *b*). The *machine* domain provides the necessary information to the *Supplier* (interface *f*), which in turn uses a *Logistics Partner* to deliver the goods, supporting the goal *Just-in-time delivery*. The shared phenomena *e* represents the delivery schedule, the goods themselves and delivery address. The *Logistics Partner* must also provide its schedule details back to the *SEJ system* (interface *d*) about its delivery (interface *c*). The *Franchise Store* also provides details of the sales of perishable goods, how the store is stocked and how this affects the sale of goods. Inventory and sales information is highly automated; its requirements can only be understood by decomposing the problems.

To meet the goal to *Develop effective decision support systems* (in RA) that helps achieve the requirements of RA, the Requirement Set RB has three goals and a number of supporting tasks. RB focuses on how the *Franchise Store* can work effectively to meet SEJ's requirements. Thus, in order to *develop effective decision support systems* one must *identify sales trends down to an hourly basis*. To meet this requirement one must have *analysis of customer needs in real time*. Allied to *sales trends* is the *constant monitoring of tastes*.

The context diagram at DB is a progression from that of DA. To meet the Requirement RB, DB's context shows the composition of the *Franchise Store* of DA. The *Graphical Order Terminal* (GOT) is a device that allows the *Clerk* to track and report on sales and stock that is held in the store (interface *k*). The *GOT* accesses the *Store Computer* by interface *h* in order to do this. The *Handheld Scanner* is a device that allows the *Clerk* (interface *m*) to scan product barcodes of items on the shelves and in the shop storeroom in order to *track customer purchasing patterns*. The *Handheld Scanner* accesses the *Store Computer* via interface *j* in order to provide regular updates. The *Clerk* also interacts with the *Point of sale register (POS)* to take customer purchases (interface *l*) and the *POS* informs the *Store Computer* (*i*) of these (described below). The *Store Computer* processes and then relays information to the *SEJ Value Net Integrator*, in real time (interface *g*), thus meeting the goals in RB critical to the success of the strategy captured in RA.

Referring to the goal model, the requirement set RC contains a number of devices. However, our focus in this example is the *POS*, represented as a GRL *resource*. It has two tasks that have to be performed to satisfy *Tracking customer purchase patterns* (in RB). These are, *Profile Customers* and *Item-by-item control*. We thus present the domains of interest in the context of the *POS* in DC.

In DC, the *Shop Customer* takes his *Products* (interface *q*) to the *Clerk* for purchase (interfaces *p* and *o*) and then pays for them (*p*). The *Clerk* scans the *Product* information via the barcode (*n*) into the *POS*. The *Clerk* enters the *Shop Customer* profile and payment details into the *POS* (interface *l*). Finally, the customer profile and product information is sent to the *Store Computer* by the *POS* (interface *i*) for storage, processing, and transmission to SEJ, meeting its goal in RB (*Analysis of customer needs in real time*) and task (*Tracking of customer purchasing patterns*). While in our model, our requirement RM refers to the

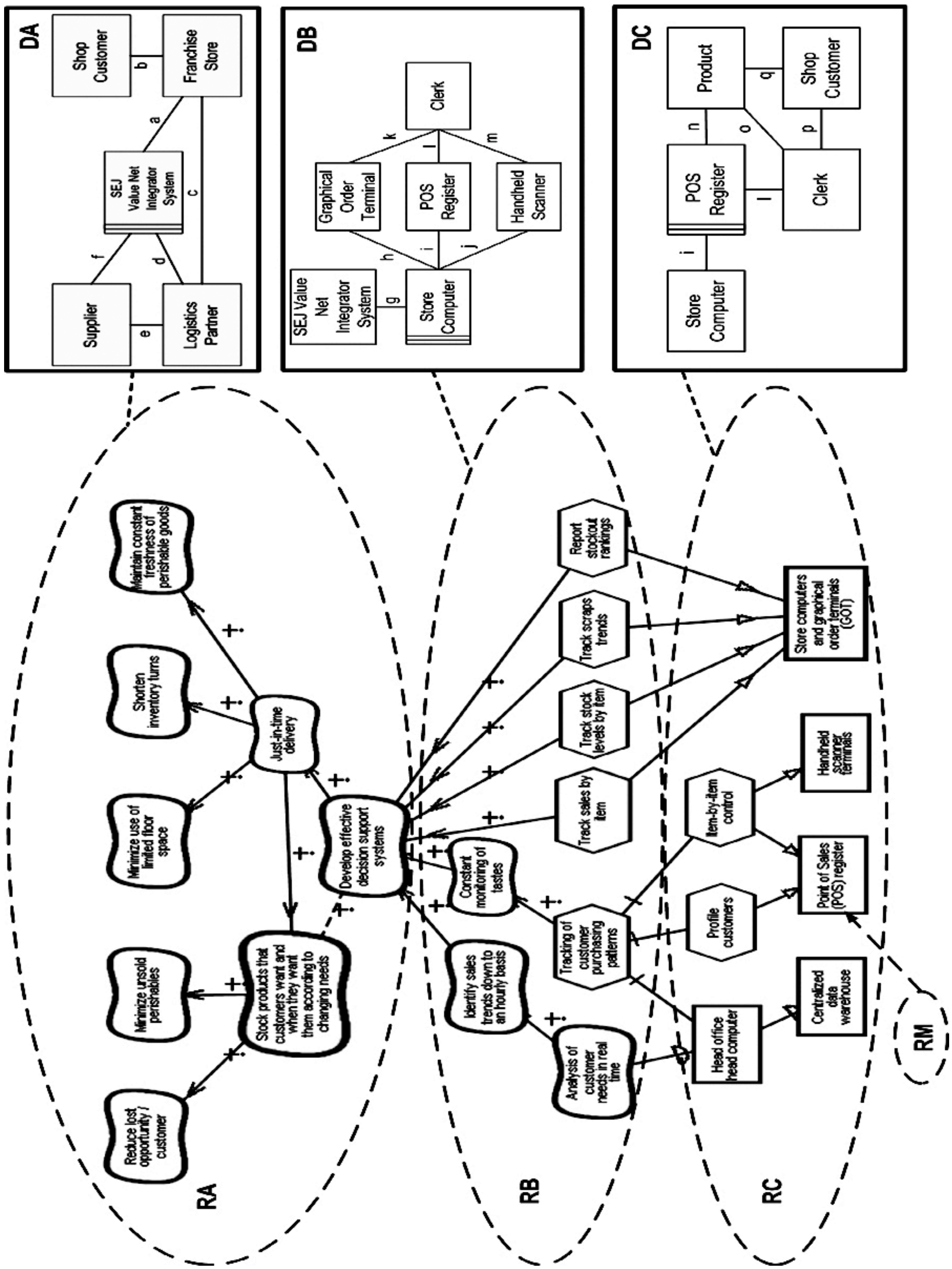

Fig. 3. SEJ Progression of Problems: Integrated Goal Model and Context Diagrams

POS register directly, we recognize that the *POS* is in fact a fairly complex machine. Its problem context would likely be decomposed into a domain DD, and further into recurring problem frames. We do not illustrate this here, because this is not the focus of our paper. Jackson describes numerous examples of this type in his book [3].

4.3. Discussion of the Integrated Approach

The indicative problem context diagrams in the progression of problems and the optative goal model mutually complement each other via integration of goal-oriented modeling techniques and the Problem Frames approach. In the integrated approach, goal modeling provides explicit linkage between requirements in problem diagrams at different levels of abstraction as determined by the context diagrams.

We also suggest problem context diagrams improve manageability of goal models of complex systems, by breaking down requirements into more manageable goal model portions. Moreover, the context diagrams enable explicitly situating individual business goal entities in the context of the problems they address at equivalent levels of abstraction. Finally, the context diagram at the top-level of the progression of problems bounds the goal model as it bounds the problem from SEJ's point of view.

Integrating goal-modeling techniques with the Problem Frames approach is however not without its difficulties. We found some awkwardness in mapping GRL goal-models to context diagrams, particularly regarding GRL *resources*. GRL *resources* are a type of entity that attempts to describe a limited aspect of problem context within the goal model. GRL *resources* are thus also represented as domains of interest in context diagrams.

At times, we found it difficult to reconcile GRL's way of describing context with that of the context diagrams in the Problem Frames approach. While both goal modeling and context diagrams employ a projection paradigm of decomposition, they do not treat entities of context equivalently. In the GRL goal model, a *resource* appears only once. The role of the *resource* at different levels of the goal model is made clear via GRL contribution links. Yet, the same *resource,* represented as a domain of interest in a context diagram, may appear in other context diagrams, as it may be re-expressed in different projections of the problem.

For example, the *POS* domain of interest appears in DB, but does not appear at all in RB, but only in RC (see Fig. 3). Yet the *POS* appears as a domain of interest in both DB and DC. This leads to some confusion for *resources* that are relevant to problem context at multiple levels of abstraction.

This suggests that when integrating goal-modeling techniques with the Problem Frames approach, it may be better to refrain from expressing problem contextual entities, such as *resources,* in the goal model. Rather, it may be better show explicit links between goals and specific domains of interest in the context diagrams.

5. Conclusions

The problem domain for e-business systems goes deep into the world, as shown in the above example. Jackson describes a requirement as "the effects in the problem domain that your customer wants the machine to guarantee" [3]. Thus requirements engineering techniques that support development of e-business systems ought to accommodate the real-world depth of the problem. Requirements engineering research unfortunately has not addressed the e-business domain in a manner that meets industry's needs.

In this paper, we present an integration of recognized requirements engineering approaches to meet the needs of the e-business systems domain. Problem diagrams provide context for the indicative business environment and can be projected down to system requirements. Coupled with this, goal modeling captures the optative requirements that fit the problem context. Each projected sublevel of the goal hierarchy in itself represents the requirements set for the context at that level in the projection.

While the approach we propose is based on research that is still in its early stages, the integration of the Problem Frames approach and goal-oriented modeling techniques may offer promise as a requirements engineering tool for e-business systems.

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