Contextually Aware Adaptive Systems for Enterprise Transformation

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Abstract. More than ever before, enterprises nowadays are faced with an environment characterised by asynchronicity, complexity, and uncertainty. We see three major shortcomings of many current approaches of enabling enterprises to adapt under these conditions: the proposed processes and systems often do not deal with the whole context surrounding the enterprise; enterprises still follow rather deliberate approaches when dealing with strategy and its execution; and decisions are limited in terms of their reach and range. Complex adaptive systems, and in particular autonomic systems, provide concepts and principles that could be leveraged to address these challenges. Furthermore, agent oriented implementation approaches could be harnessed to realise contextually aware and adaptive enterprise systems. In this paper we propose an adaptation lifecycle model, an agent oriented framework and architecture that enable enterprises to learn, adapt and be transformed.

Keywords: context, adaptive, agents, autonomic, enterprise transformation.

1 Introduction

Today's business environment is unpredictable, complex and uncertain. Enterprises that want to compete in this dynamic environment need to be able to respond rapidly and adapt to the ever-increasing rate of change. They have to overcome complexity, uncertainty, and rapid change at all levels of their internal and external environments [9]. Enterprises are wide ranging in terms of space and time. Enterprises need to be able to reach anyone, anywhere, anytime, and be able to conduct simple to sophisticated transactions in automated to semi-automated ways. Much of the current business environment change is driven by an insatiable customer demand for new, competitively priced, innovative products and services. These customers are less brand loyal and want greater choice resulting in the need for enterprises to constantly innovate. Yet, there is a global shortage of resources, such as business talent and investment funds, to fuel this innovation. Added to these factors is the relentless stream of mergers and acquisitions that change the enterprises operating environment. This volatility of the business environment creates uncertainty that necessitates change in terms of the way business is conducted [4]. This means there is a

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corresponding change in business models along with the business processes (BP) and technology requirements that support those models [2]. Customers demand that their orders are fulfilled promptly so BP need to be created and executed quickly resulting in demand spikes for resources and sophisticated services. To address these problems, issues, and requirements we propose and discuss a contextually aware model, framework, and architecture that enable enterprises to learn, adapt and be transformed. This paper primarily consists of two parts. The first part explores the concept of an enterprise as a complex adaptive system (CAS) and the issues associated with enterprise adaptation. The second part proposes a conceptual model and framework that attempt to address these issues, especially in context of a contextually aware adaptive enterprise (CAAE). Finally, an agent-based system architecture to realise the proposed framework and support our model of enterprise adaptation is introduced.

2 Contextually Aware Adaptive Enterprise

Scheer [20] argues that for enterprises to be adaptive they need to balance flexibility with stability. He suggests that low levels of connectivity and high levels of control prevent flexibility and creative behaviours. The presence of rigid enterprise structures and rules and the lack of communication and interaction mean the work processes are set and people isolated. Scheer goes on to suggest that enterprises with traditional top down hierarchical management structures have high levels of intensity of control and low connectivity. In contrast, there are enterprises at the bleeding edge that are very reactive, connectivity between parties and the external environment is very high. They are constantly sensing the environment and trying to respond to change. However, these kinds of highly reactive volatile enterprises, such as many high tech start-up companies, have low levels of intensity of control [20]. Neither of these extreme positions is good [6], [20]. One is characterised by deliberation, control, and stability and the other position is characterised by chaos, flexibility, and possibly innovation and even anarchy. Scheer [20] suggests that the best place is to be on the edge of chaos where enterprise's balance flexibility and stability.

Based on the previous discussion we define the adaptive approach as a combination of deliberate approaches that support stable, evolutionary growth and emergent approaches that support more opportunistic, organic growth. A CAAE should interweave the deliberate and the emergent aspects of each subsystem of Scott-Morton's MIT90s framework [21] to form a cohesive adaptive whole. One way to conceptualise this notion of an adaptive enterprise as a CAAE is to interpret it as a Complex adaptive system (CAS). A number of authors have argued that an adaptive enterprise exhibits the generic constructs and operating mechanisms of a CAS [19], [10], [14]. In CAS, many agents, (may represent individuals, populations and enterprises) as part of a dynamic network, are constantly interacting and learning from those interactions to enable the enterprise to adapt [10]. A CAS can be described as a self-organizing system, consisting of multiple interacting components that emerges over time into a logical form and freely adapts without interference [14].

CAS theory has generated considerable interest within the management and organisational domains over the past decade. Topics such as enterprise transformation [17], strategy [13], innovation [6], and Information Systems [18], have been examined using a CAS theory lens. In these domains a CAS is viewed as an adaptive social system with a number of defining characteristics. At its core is a diverse population of agents (individuals) who are interdependent and linked together in causal relationships. These agents are also extremely context specific and their response to the same stimulus alters according to the current environment [14]. More recent concepts and models of an enterprise as CAS emphasise the characteristics of internal mechanisms of connectivity, self-organisation and emergence, as well as the interaction between the system and its environment, which results in the co-evolution of both [18] Given the aforementioned theories and models, the key characteristics of CAS used to define the concept in this research, are as follows, [19]. CAS are nested systems made up of various agents that can also be deemed as systems in themselves. Each system is part of a system hierarchy and can be either a sub-system or supra-system. CAS are unpredictable and dynamic, their control is decentralized and distributed throughout the CAS, which often leads to seemingly undirected chaotic system actions. Inherent in this seemingly lack of control is a feature of CAS known as emergence, namely the emergence of system's outcomes through the process of self-organisation rather than directed interference. The majority of changes in complex systems are considered to be emergent where patterns of actions are not deliberately designed. The interaction of the agents generates patterns of actions over time that regulates the action of the systems as a whole leading to further adaptation of the CAS. The key drivers of this adaption are: interactions between agents that can lead to positive or negative action outcomes, information flows, operative feedback loops, and time [14].

3 Managerial, Technological and Autonomic Approaches to Enterprise Adaptation

Many models for enterprise adaptation have been suggested but most of these models are either management oriented or technology oriented. In this section we first review the management and technology approaches to enterprise adaptation and then explore the autonomic approach. In particular, we explore the complementarity and potential enhancement of the management and technological approaches when interwoven with the autonomic approach.

Bhattacharya et al.'s [5] framework and Kumaran et al. [16] transformational approach are some of the few models for enterprise adaptation that interweave managerial concerns with technological responses in an integrated and holistic fashion. Bhattacharya et al.'s [5] framework differentiates four different models on different levels of abstraction. The strategy level model is at the highest level of abstraction, where business objectives are specified. These objectives drive the operational models. These models describe the structure of enterprise BP. In order to support enterprise BP with information technology, solution composition models are

designed that combine necessary information technology functionality and the operational models. Solution composition models can be seen as an intermediate layer between business and information technology; rather than having to deal with implementation specifics, "solution architects" can operate on a more abstract level that simplifies the matching of business requirements to IT. This is sometimes referred to as "programming in the large" [11].

The Autonomic Systems (AS) computing paradigm is a key element of the autonomic approach for enterprise adaptation [8]. AS are able to self-manage, self-heal, and self-optimize. They are environmentally aware and operate intelligently and dynamically [22]. AS make autonomous decisions based on high level guidelines, the systems will constantly sense and optimise their status in order to dynamically adapt to the changing environment. In the AS paradigm the human element adopts a new role, rather than controlling the systems directly people define the guidelines and rules that support the self-management process. It can be argued that CAAE can leverage the automaticity and cost advantages offered by AS to augment and enhance their adaptive behaviours and ultimately transform the enterprise [15].

However, there are certain organisational processes that cannot be extensively automated such as the meta-decisional processes of strategy. The development of an enterprise's adaptive strategy is essentially a human activity that requires largely manual intervention. AS can support strategy development through the generation and migration of emergent patterns from the lower operational level of the enterprise. It is at this level emergent patterns are generated by the AS as they autonomously perform standardised BP. These patterns flow through the intermediate BP level to become the emergent input into the strategy development process. Conversely, once the strategy has been developed it is implemented at the intermediate and operational levels through the AS policy and rules, which guide the systems' autonomous decision making. A strategy that embraces the AS model significantly enhances an enterprise's ability to continually adapt to its environment through the generation, translation, and integration of emergent patterns into an adaptive strategy for sustainable competitive advantage.

Although strategy does not completely align with the AS model, other organisational level activities do lend themselves to automatic changes in the parameters. For instance, changes in the form of emergent patterns captured by the AS at the operational level of the enterprise can act as precursors to the creation of products and services that provide competitive differentiation. The creation of these products and services come about through the execution of higher level, cross-enterprise, innovative BP [3]. Essentially, AS enabled, standardized BP activities are used to compose AS enabled, composite BP. These composite BP, in turn, are orchestrated to become new, innovative BP for business growth.

4 Contextually Aware Enterprise Adaptation Lifecycle

A synthesis of the above concepts with respect to learning, context, adaptation, and strategy-driven processes and systems leads us to propose a model for enterprise adaptation (Fig. 1) that leverages the AS computing paradigm. This model explicitly

considers the transformation of vision and strategy into appropriate enterprise BP. It considers the translation of these BP into potential solutions that compose and integrate activities to deliver effective and flexible implementations. Execution and monitoring of the implementation and contextual actions (internal and external CAS outcomes) enables us to pro-actively manage the performance of the enterprise through three distinct mechanisms; corrective (single-loop learning), optimising (double-loop learning), and aligning (double and triple-loop learning). These actions are captured and made available through information and communications technologies [8]. One such technology is (AS), they could be present within the enterprise capturing internal actions and presenting them to internal and/or external consumers. AS can potentially provide new and better options for enterprises to respond and adapt to their rapidly changing environments.

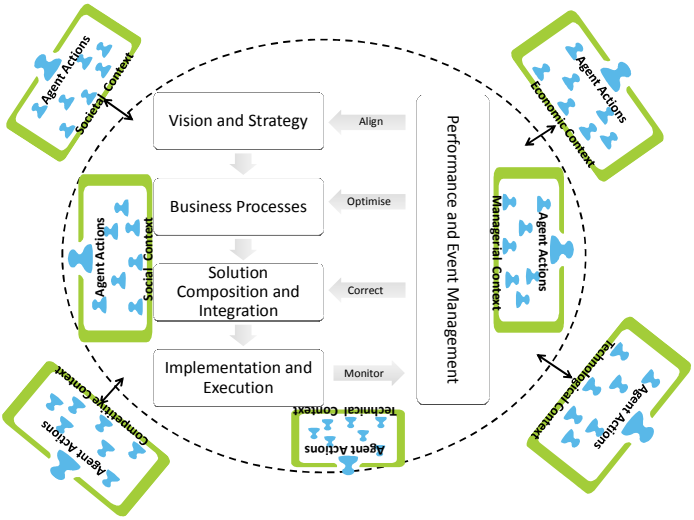

Fig. 1. Contextually aware enterprise adaptation lifecycle

5 Contextually Aware Adaptive Systems Framework

New paradigms of management for adaptation (and innovation) depend heavily upon technology. Open innovation (and adaptation) is difficult to implement without technological mechanism to access the knowledge of the various stakeholders. We suggest that technology should not be seen only as a means to achieve ends determined by a higher conceptual level but also as an integration, coordination, and collaboration mechanism to facilitate change. To illustrate this perspective of technology as an integrator, coordinator, and collaborator to drive change and to support our model of enterprise adaptation, we propose a contextually aware, adaptive, AS enabled, conceptual framework (Fig. 2). In this framework, technology is understood as a central mediator between the different kinds of context. Each context (internal and external) is a CAS in its own right, populated by agents and serves as an integral part of the environment in which it resides. The actions

(behaviour) of agents are tightly tied to the actions of other agents through interactions that can lead to positive outcomes which cause the system to change through adaptation. The whole learning and changing process, or process of enterprise adaptation as described above, is mediated by technology some of which are AS. These technologies work as mediators between the context and the enterprise levels of strategy, BP and operational implementation. The mediation should, on the one hand, help to channel actions for the decision maker, which can be either AS at the lower organisational level or a human at the higher level. On the other hand, technology should help to transport the decision maker's decisions back to the context. For instance, if a change of strategy is decided upon this change must be reflected in the operational plans and communicated to decision makers (human or AS).

The proposed framework illustrates that actions (agent behaviours) originating from AS can be of different natures as they might originate from different contexts (Fig. 1). Real-time actions are a type of 'event' traditionally emphasised in discussions of event-driven architectures. These predominately allow capturing actions from the managerial and competitive context. Transactional actions are actions occurring in the predictable course of a BP.

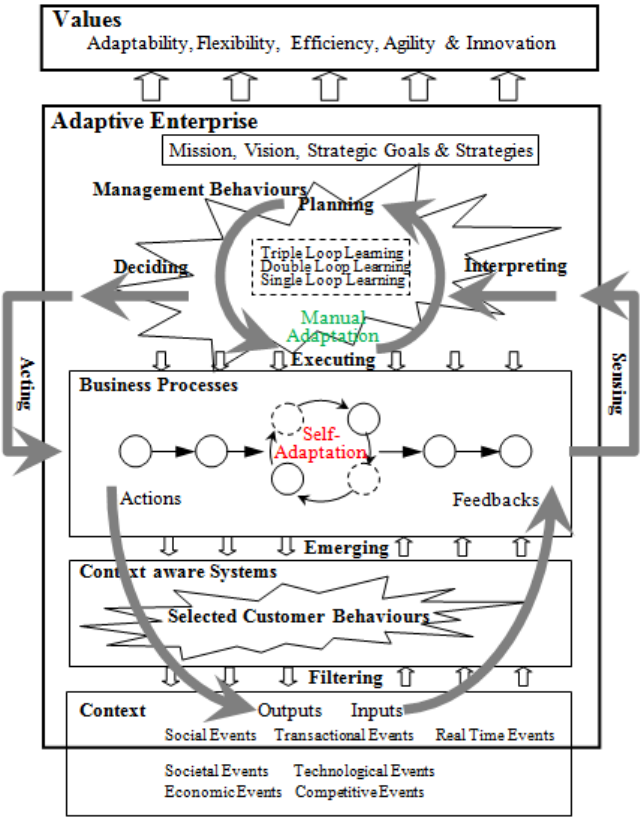

Fig. 2. A framework for contextually aware adaptive systems

Our framework emphasises the importance of capturing unpredictable competitive, social, managerial and technological actions through AS enabled technologies. We see these actions as primarily driving an enterprise's ability to learn and adapt to novel circumstances. This can be, for instance, the dissatisfaction of an employee (agent) with the way he has to conduct his work. There must be channels in which he can articulate his concerns and which directly influence decisional processes including the meta-decisional processes of strategy that influence enterprise reorientation. Capturing the actions of agents is an important aspect of managing emergent developments in formalised channels, as discussed above, and ultimately integrating the deliberate approach with the emergent approach.

The framework distinguishes three central learning processes informed by Argyris and Schön's notion of single loop learning and double loop learning [1]. Single loop learning occurs when BP are improved on an operational/implementation level. This learning process is driven by actions deriving from the external context and is technology-mediated. The actions arrive at the social, technical and managerial subsystems and filtered by technology. Based on these actions, the changes that the decision makers decide on are made a reality using technological means. Double loop learning occurs when the controlling subsystem reacts to actions, leading to a change of BP or enterprise structures or both. Triple loop learning occurs when the meta-level subsystem of the enterprise reacts to actions by changing the enterprises strategic direction. Besides single loop learning, which in some instances can be controlled by AS, the learning processes that enable the enterprise to evolve and adapt require a decision maker or a collective of decision makers to take a decision.

6 Contextually Aware Adaptive Systems Architecture

To meet customer demands in the rapid changing business environment, context aware BP and management systems are open dynamic systems. Incorporating adaptation to changes into BP makes them more complex than the traditional BP approach. Software agent based, oriented and coordinated BP help to address this problem [7]. Business activities in a BP are services provided by software agents. These services are proactive or reactive. The proactive services are aligned with business strategies and policies. The deliberative software agents have goals and plans to execute in order to achieve the goals under the facts that software agents believe the context existing in the current business environment. The reactive software agents respond to the situations with defined rules. Goal oriented BP can achieve full alignment to strategies set by top management. Each activity in BP is a service. The services used to support BP can be classified into three categories, routines, rule-oriented and goal-oriented. Routine business activities do not need changes. The rule-oriented business activities make decisions based on the setup business rules. These rules reflect business policies. Rules are determined by management and can be changed after initial setups. The changes or updates of rules are performed manually by employees or automatically by intelligent software agents. For goal-oriented services, each service has a goal and plans to achieve that goal. The plans can be

activities or sub-activities. The BP can be configured and re-configured by business owners manually (e.g. by business rules) or by intelligent software agent automatically based on the existing business context [7].

In this section, we design a software agent-based contextually aware architecture (Fig. 3) to realise the proposed framework. In the architecture, software agent services consist of intelligent and mobile services. Software agent services can either be proactive or passive reacting to actions initiated in the contexts to provide agile changes required by the enterprise. Software agents can be stationary or mobile. Mobile agents can be sent to the business environment such as customer devices to collect context information. The different kinds of actions that drive learning in the framework require different kinds of software agents to act upon. Based on the internal and or external actions sensed and collected from various context systems, the goal seeking or deliberative intelligent agents select the plans to change the BP to adaptive to the changes detected from the environment. This is called self-adaptation.

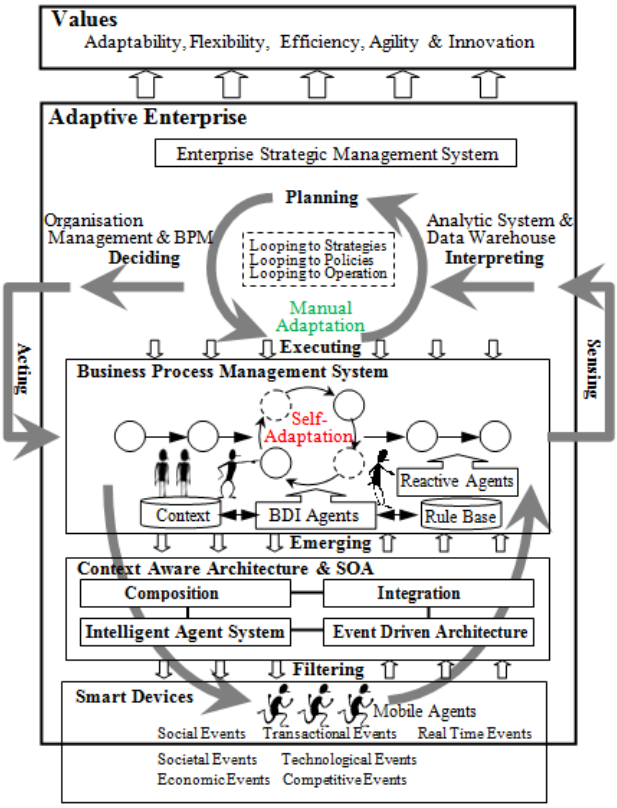

Fig. 3. An architecture for software agent-based contextually aware adaptive systems

Alternatively, the decision makers interpret the implications of the actions. Then they design responses using service integration, orchestration, choreograph and improvisation within the enterprise or across enterprise boundaries to achieve different levels of adaptability for enterprises. The changes can be made by changing the business rules for the BP. The reactive agents pick up the rules to implement them at the BP to reflect policy or strategy levels to support integration, coordination and collaboration within the enterprise and across organisational boundaries. This is called manual adaptation. The combination of self-adaptation and manual adaption makes the contextually aware action driven architecture provides enhanced flexibility, agility, and ultimately adaptability in comparison to more traditional system architectures.

Software agent-based contextually aware adaptive systems can be implemented for inter-organisational business integration (virtual enterprise for employees) and intra-organisational collaboration (virtual enterprise for networked business partners). Our argument is to use both approaches for innovative, adaptive enterprises. Transactional actions are traditionally handled well by ERP systems or service oriented architectures (SOA) whereas real-time actions can be processed using Event Driven Architecture (EDA) systems. Mobile agents can be sent to various business environments to collect social, technological, economic, and competitive action information. Other existing technologies can also be used to implement software agent based context aware systems for virtual organisations. At the context sensing layer, Web 2.0, EDA, CRM and social networking technologies can be applied to detect actions from various sources. While at the interpreting level, BPM, rules based systems, databases, and business intelligence technologies can be used to analyse the activities and contexts. Data mining and decision making technologies can be employed for strategic planning and selecting at the planning and deciding layer. At the acting level, ERP and BPM technologies can be utilised for performing and monitoring the operations responding to the actions detected. At the organisational structuring layer, grid, cluster, Web services, SOA, virtualisation, software agents, enterprise portal and middleware technologies can be exploited to integrate various enterprise information applications in a traditional system landscape.

7 Conclusion

It is a common thread in many streams of research, such as Enterprise Systems implementation, that information technology (IT) is not the remedy for enterprise inertia. Many factors besides the technology must be considered in order to achieve positive enterprise transformation. However, one common theme still persists in the literature; IT is often seen as a central enabler of enterprise change. In this paper we to argue for redefining the perspective on what adaptive IT can and cannot do and suggest the notion of IT as mediator of enterprise change rather than an enabler. This next generation of adaptive IT uses context as a driving force for technology-mediated enterprise change. Truly adaptive systems are not merely technological systems. They need to be strategy driven, learning oriented, process oriented, and

service oriented to be truly adaptive. Consideration should also be given to the rapidly evolving managerial, technological, social, economic, and competitive contexts. In this paper we first investigate the notion of enterprises as multi-dimensional, complex, and context aware systems [12]. Given this, we reflect on the traditional perspectives of seeing technology as the central enabler of enterprise change. We contrast this with recent literature that emphasises the importance of linking the deliberate approach with the emergent approach in order to achieve an adaptive enterprise. Based on this discussion, we propose perceiving technology as a multi-dimensional mediator of context-driven change. To demonstrate this notion we propose an agent-based framework and architecture of a contextually aware adaptive system for enterprise adaptation. We posit this is one possible way for enterprises to adapt in a changing world of complexity and uncertainty.

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