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Abstract

In a fashion similar to the biological study of cell, tissues, organs and organ systems that make up biotic species, we look at e-business software infrastructure as an architected collection of software building blocks: class (in an object-oriented sense), interfaces, programs and systems in support of the functioning of an enterprise in e-business. The interaction between the software created from these building blocks can be as simple as a function call and data transfer between one short calling program and another (called) program acting synchronously or asynchronously or as complex as commonly found in today's multi-threaded, load-balanced, load distributed, disparate destination-based, n-tier client/server applications and/or enterprise-level process-based systems. The software building blocks supporting the e-business may be written in different languages at different time, reside on different platforms and may have completely different message formats and structures that need to be integrated for the operations of different business processes. The structure, function and behavior of software and the interaction between various software building blocks become very complex, since the building blocks evolve over time due to the reusability of code via class hierarchy, inheritance and interface much like genetics and evolution of species. Thus when software is considered as biotic and living species with and without the presence of abiotic influencing factors defining its environment e.g. finance, talent, investment, and the like, we may introduce the notion of *ecology of software* for the purpose of studying the life and death of software products, their behavior and their impacts in defining and servicing the new economy. Clearly, we can distinguish two scopes of software ecology: (1) interaction within the software itself and (2) interaction between software and its environment. This paper addresses the former: the ecological aspect of the software infrastructure of e-business. Our discussion will be limited to the introductory, parallelic considerations between biotic system and software systems. The discussion on the latter scope will be addressed in a subsequent paper.

E-commerce, e-business and supporting infrastructure

With the explosion of the Internet use, the selling and buying of goods and services on the Web, commonly labeled as e-commerce or part of the e-commerce, also explode at an unbelievably rapid speed. The reasons for companies to turn to the Web for e-commerce can be completely different from one company to the next but they can be viewed as derived from a major reason: cost reduction in providing timely customer service and good delivery while aggressively trying to reach an increasing larger customer base and customer satisfaction. Giga Information Group (Giga, 1999) estimates that by year 2001, this market will reach anywhere between 570 billion to 970 billion.

As an example of an e-commerce usage, in one Web page or a couple of pages, a consumer/customer can perform online booking for airline, hotel, car and purchase anything else they desires, or download and apply maintenance code for a particular product via an Internet portal. An aspiring entrepreneur who desires to provide a new business service via Internet without any prior knowledge on what and how the supporting infrastructure has to offer him/her, can setup his/her business on the Web rather quickly. At a click of a button, the entrepreneur has a choice of DSL (Digital Subscriber Line) at an affordable speed, a selection of a preferred ISP (Internet Service Provider), with appropriate ASPs (Application Service Provider) and others business service providers (BSPs). S/he may have a selection of providers for his/her marketing/sales/communications of good and/or services, for supporting business requirements such as finance, accounting, legal, supply chain, manufacturing inventory, distribution, and the like. An executive, at the request of a client, may bring up an enterprise portal in which all information pertaining to the his/her topic of interest may be collected and presented for his/her decision.

The success of e-commerce market and tools depends a lot on the effort of a larger domain called e-business that is typically unseen by the Web consumers/Web customers. The e-commerce therefore is just the tip of the iceberg. Underneath the tip of the iceberg is a huge supporting infrastructure for e-business organized in different vertical and horizontal functions and layers. These include the physical network, the traditional connection-oriented and connectionless communications, the message-oriented middleware, the n-tier client/server system, the brokering services for integrating disparate message formats with intelligent routing and dynamic transformation, numerous pre-packaged software and the workflow management systems automating the business processes of an enterprise or across different enterprise.

The infrastructure supporting e-business is therefore very sophisticated and complex. The technical effort involved in providing e-business solutions similar to those in the previous examples is enormous since it must cover

the complexity of numerous chained and loosely integrated business applications. The applications exist in different platforms, running on different hardware, have different data structures and types, executed by programs written in different computer languages, using a wide range of technologies. A great deal of effort is given to provide the integration of those supporting software so that changes to any reservations in the first example would trigger an automated change to any other reservations (automated trigger of one business service to another). Notifications and confirmations would be sent to the customers in due time in the form of e-mail message, pager or any other means. If any booking fails, alternatives will be offered for customer's selection of another available service provider (hotel, car, and the like). Similarly, any time during the course of business setup or operations of an entrepreneur in the second example, if s/he is unhappy for any reason with any of the providers supporting his/her business, availability of provider replacement will be at his/her disposition.

The evolution of MOM, COM/CORBA, EAI, XML, and many other technologies holds excellent promises to providing services to consumers as exemplified previously. Furthermore, business partnerships for business-to-business therefore have been and are being formed to quickly respond to customer needs since no single vendor can make it happen alone. Even within an enterprise, cross-functional process between sales automation force to accounting, finance, manufacturing, supply chain management, inventory, production, distribution, and customer relationship using ERP, MRP, CRM and many pre-packaged software are receiving the utmost attention from top management and business leaders.

This supporting infrastructure, its functions and its behavior are the areas of attention in our study and research from an ecological aspect. In this paper, we parallel the making of e-business infrastructure in a fashion similar to that of living species and introduce a set of concepts and generic scheme for an initial understanding of its behavior in the next section. Then, we look at our initial description of e-business infrastructure as an ecological system and discuss an approach to behavior of e-business infrastructure in a context that we will call the "ecology of software". Our concluding remarks on this positioning paper and where this research will lead to will be summarized in the last section.

The making of e-business infrastructure and modeling e-business infrastructure for behavioral understanding, problem solving and prediction from a biotic aspect

An example of a functional cut through an e-business of an enterprise to define e-business infrastructure is given below to show an aspect of software interaction in a *community* of software for business solutions. A consumer via a Web browser makes an order online and sends the order via the Internet to the enterprise Web server. The order can be handled with a home grown Web server application or with the help of an ISP (Internet Service provider) in conjunction with an ASP (application service provider) or BSP (business service provider). In a successful scenario, the order may reach another server for checking consumer's creditability. The approved order can then be forwarded to manufacturing and/or inventory for assembling and making of the ordered items. This may involve other e-businesses (business-to-business) in the supply chain. The finished items will then be sent to packaging and distribution for shipment. Billing record can then be prepared for the purchased items. In the business process example, a particular server can be at any location, running on any kind of platform, and communicate with any other servers in the chain. Data can be of any format types between different servers of the enterprise. Related messages for the execution of this online order (notification, purchase order, billing record, supplied item descriptions, or destinations) can be moved between servers synchronously or asynchronously. Errors can be logged, reported, audited, traced and repaired. The functional cut behaves in a fashion similar to functional organ systems in living species (e.g. circulatory or digestive system).

Borrowing the concepts of cells, tissues, organs and organ systems in biology (Solomon et al., 1996), we parallel the making of e-business software products as an organized collection of building blocks: class (in the object-oriented sense), interfaces (in Java sense, similar to the idea of membranes of cells in living species), applications and systems in support of the functioning of an enterprise or cross-enterprise organizations. Loosely speaking, when ions, atoms and molecules of elements make up an organism (e.g. O, C, H, Ca, K, Na, and the like), zeros and ones in binary system make up software elements that define life for class objects, interfaces, subsystem and system. In a human body, for example, at any time, there are million of interactions between ions resulting in chemical signals and reactions in the forms of proteins to keep the body alive, in the e-business, there are millions of bits and bytes floating in its cyberspace attempting to perform different actions to keep the e-business alive. When cell is the smallest unit of biological life, object class (in the sense of OO) is the smallest unit of software life. When biological membranes in cell or between cells are junctions between biological pieces, programming methods and interfaces can be considered as junctions between pieces of software. Assembler program inline macros, COBOL copybooks, C and C++ include statements, Java import statements, and C++ and Java class hierarchy and inheritance, a server piece of code, its containing server or aggregate server are examples of implementing the concept of reusability. The

reusability of code creates new code much like the mating of species to generate different phenotypes from a given set of genotypes. If genetics and biological evolution are the continuation of species life then reusability defines the continuation of software life and its evolution.

Continuing this line of parallelic thinking, the e-business infrastructure supporting e-commerce described via the above simple and typical example suggests some interesting considerations. First, how the creation and development of a new software product or the integration of software application and system can survive and what would constitute their success and survival in the community of software? Second, why some operating systems or shrink-wrap and business applications are disappearing or become less and less used while others become dominant in the market place given the fact that they are all derived from a common set of software "genotypes"? Third, what can be said about the influence of factors such as investments, talent, cost, time, organization, process, technology, resource and the like (paralleling the environment influence and abiotic factors such as energy, water, temperature in the ecology of organisms). And finally, how and how much a newer economy influenced by software can be predicted?

An ecological approach to e-business infrastructure behavior - The ecology of software

Research questions to be asked in an ecological context such as those mentioned in the previous section are numerous, however they can be generally classified in three categories. The first constitutes those questions that deal with e-business infrastructure that would yield non-functional objective such as optimum performance, availability, reliability, and the like. The second deals with how a software ecosystem would behave when changes are incorporated into the system. And lastly, the third deals with what can be predicted in terms of impact to the e-business environment and economy.

To develop a better understanding on this complex e-business infrastructure from a biotic aspect, we place our emphasis, not on the building blocks themselves but on the interface between building blocks at different level of complexity. At the business process level, it is the interprocess. At the integration and broker level, it is the mapping between output and inputs structures of various participating software. At the functional level, it is the calling/called sequence (procedural or object oriented), and at the data level, it is the transformation, migration, infiltration and routing of information/data vertically and horizontally from one format/structure to another.

We introduce three underlying concepts forming the interaction between software products in e-business infrastructure: *configurability* (structure), *mappability* (function) and *interoperability* (behavior) in providing transparency and distribution of software and services. In *configurability* we describe software as "*points"* in a community space, *mappability* as "*lines"* connecting different products (hence software connector) and *interoperability* as "*surface or volume*" in which products are to be interchanged (hence software broker) and describe them in the context of a pedigree of software. This gives rise to an identification of irregularities such as isolated points, isolated polygonal lines, and opened surfaces as software phenotypes that have little to contribute to the overall software ecosystem. This in turn allows us to apply criteria evaluating software products as contributors to the economy, which are influenced by such factors as investments, finance, developer talent, resource constraints, process, and the like to the life and death of software products.

Concluding remarks

The e-business discipline and its market are rather new but fast growing. Most attention has been paid to e-commerce until the complex support to e-commerce by e-business and required infrastructure becomes a fact of life. As usual, business/industries are busy creating even more complex solutions to business cases and scenarios with little attention to the long-term survival of the products in their complex environment. The search for answers to the questions generally posted in previous sections can be found by approaching software from an biotic and ecological aspect since the similarity between the making of e-business and living species is found to be significant. Furthermore, factors such as cost, talent, time, organization, technology, process and the like can be injected into the e-business equations as environmental influence and resource constraints, much like natural energy, water, temperature and other abiotic factors that influence the ecology of organisms (Krohne, 1997). The results of modeling e-business in general and e-business infrastructure in particular for the understanding and explanation of its behavior and impact to enterprise and global e-business and the new economy when exposed and analyzed from a biotic aspect and from an ecological aspect will be reported in subsequent papers.

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