The Rise of the Intelligent Enterprise

By Kemal A. Delic and Umeshwar Dayal

Mother Nature knows best -- How engineered organizations of the future will resemble natural-born systems.

The history of fascination with machines that can emulate certain human behaviors dates back a couple of centuries to some ingenious people who invented a whole range of automata that could play music, dance, understand certain words, or even appear "intelligent." [For an overview of this subject, see Gaby Wood's *Living Dolls: A Magical History of the Quest for Mechanical Life.*]

More recently, in the 20th century, the mathematician Turing established a test for "artificial intelligence" (AI) according to which the ultimate proof is the inability of a human jury to distinguish machine answers from human answers. This eventually triggered half a century of research into AI. While the elusive objective of this research was to create AI itself, the most concrete outcomes are found at lower and more modest levels. In the same way medieval alchemists trying to turn dirt into gold, while never reaching their original goal, nevertheless invented many valuable chemical processes and useful devices.

Thus, we can see today some AI-based, practical solutions embedded, for instance, in modern cars (anti-skating), medicinal devices (initial image analysis), industry (robots, voice-recognition, resource scheduling), etc. It would seem that AI is presently most successful where it is somewhat hidden in the form of crucial, dependable and working embedded technologies. One may argue that developments in the field of Information Technology have been the key for such "intelligent developments".

Science fiction authors and moviemakers have had much more freedom to indulge their dreams and fantasies in this area. Being futurists and projecting possible worlds of tomorrow, they have long depicted intelligent things, humanoid robots, smart cars, intelligent buildings and cities. While such visions have not been entirely fulfilled, some correspondence with modern reality can be discerned. In a similar spirit, this article will outline a vision of the future Intelligent Enterprise (IE) -- a business corporation morphing into a complex system able to behave as a biological system or ultimately to act as an intelligent human.

Intelligent Enterprise Defined

The notion of the IE is characterized by the ability of businesses to morph into new forms/entities with some surprising results. Today's enterprises deploy IT to do their business, which introduces significant complexity. This technical complexity combined with organizational complexity can and does create internal "islands of inefficiency" that are difficult to deal with. We envision that in the future IEs will (automatically?) transform themselves into better forms by becoming "more intelligent". They will derive efficiencies through the automation of their core business processes, and the exploitation of knowledge. Agility will be improved by one or two orders of magnitude, intelligence density within the enterprise will grow sharply and problem-solving capacities will be dramatically enhanced. They will form dynamic partnerships with other enterprises to create dynamic business ecosystems, which will be self-managed, self-configured and self-optimized. Consequently, they will exploit new forms of business value creation, adjusting their behaviors to the markets by learning from them.

The question may arise why we are comparing engineered systems to biological, natural systems? And why do we assume that adaptation is a key behavior? This comes from our belief that both systems share the same ultimate objective: to survive in an evolving environment and changing circumstances. To achieve this, a system should be able to sense its environment, to understand the situation and to create a viable plan that will be then reliably executed. A system should also exhibit learning behavior. Engineered systems will likely never reach the level of sophistication, elegance and beauty of nature-born systems, which from the pragmatic point of view serve as the ultimate ideal to strive for.

Looking at current large and successful businesses, one can observe that many have already deployed some primordial forms of the future intelligent enterprise. The current acronym soup of CRM, ERP, EAI, EKM encompass enterprise activities aimed at improving efficiency or injecting intelligence into their operations.

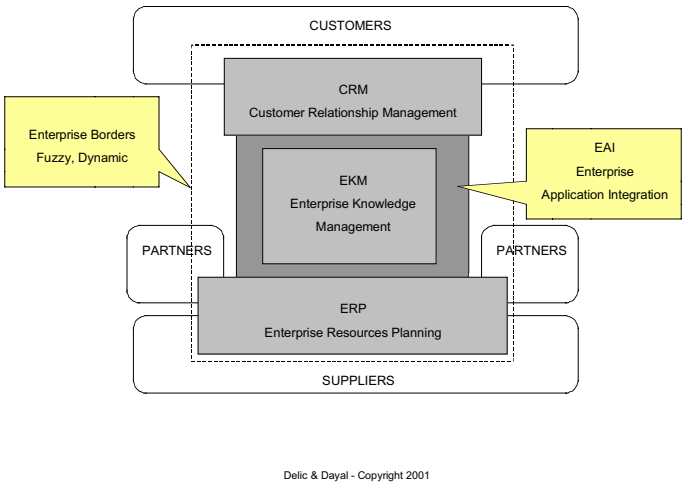

Figure 1 : Generic Intelligent Enterprise Architecture

CRM (Customer Relationship Management) serves to understand, maintain and improve evolving customer needs. **ERP** (Enterprise Resource Planning) addresses issues of supply chain efficiency and back-office optimization. **EAI** (Enterprise Application Integration) aims at the integration across islands of functionality, by not only providing connectivity and communication, but through the orchestrated functioning of all enterprise sub-systems. **EKM** (Enterprise Knowledge Management) is a broad area whose ultimate objective is to inject knowledge into business processes, enable reuse of human expertise and to create system artifacts with rudimentary intelligence.

Intelligent Enterprise is therefore:

1. agile -- It can launch a production order very rapidly after, for instance, closing a Web-based purchase.

2 adaptive, self-regulating, self-optimizing -- It can adjust key business parameters (revenue, profit, cost) to the short-term, changing business climate.

3 with fuzzy borders, mesh-like structure -- It can restructure and scale the organization to fit dynamic needs. As in outsourcing or complete outsourcing, for example

4 self-aware, aware of the markets and able to learn from them and adapt to them -- It can deal with internal inefficiencies, bottlenecks and latencies and coordinate them with perceived market changes, for example, knowing the level of goods being produced, correlating this

information with the market niche real-time situation, and jumping quickly into a price reduction campaign on the Web

5 - able to morph into new and better forms -- this is a long-term process in which we may not even guess what will the final form look like. It will include not only adjustments of the business and operational parameters, but also major structural changes; deciding for mega-merge or drastic resizing while changing the industry branch, for example.

In a very rough analogy shown in the Figure 1, we may recognize enterprise sensors, effectors, a nervous system and brain corresponding to those of living organisms, each with particular functionality. CRM provides sensing functionality; EAI may represent nerves interconnecting ERP effectors with CRM and EKM being dispersed across enterprise, but centrally coordinated from the brain (company top management). The best current guess is that the future IE will be a hierarchically organized, decentralized and distributed system with a high level of self-regulating, local autonomy. Some authors are reporting about implementation of such systems combining component-object technology with intelligent agents technology to create complex adaptive systems [1], using Web-services as the glue for heterogeneous enterprise applications [2] or a wide variety of enterprise middleware technologies for integration purposes [3].

Evolution towards Intelligent Enterprise

One may wonder why contemporary enterprises are not already exhibiting these features and what's preventing them from doing so? It is very likely that the uncoordinated development of the above mentioned domains by several fiercely competing vendors -- each lacking a holistic view or suitable integration framework (as is IE architecture, for example) -- are possible causes for US corporations having spent approximately 700 billion dollars (est. between 1995 and 2000) on enterprise software that is not used very effectively today [*Financial Times, Dec. 5, 2001*]. Two thirds of that amount was spent on "custom-built" programs known as the "bridges".

Therefore it seems likely that those who will be able to solve the challenging problems of interoperability, cost-effectiveness and reflectivity (reduced latency) may claim that they have entered into an IE-morphing phase.

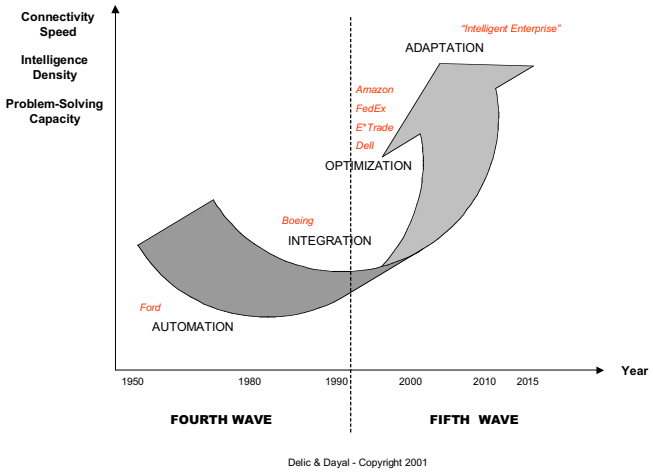

Figure 2 : Evolution of the Intelligent Enterprise - Next 15 Years

In Figure 2 we sketch a possible evolution to model-corporations illustrating four characteristic phases of the last two technology waves. These corporations dominated markets by deploying large-scale automation methods (e.g. car assembly lines), integration (e.g. huge numbers of avionics suppliers for several hundred million pieces) and optimization (e.g. clever synchronization of order, supply and assembly chains combined with financial engineering).

We envision that "adaptation" will be the key characteristic of the fourth phase in which "intelligence density" (widespread use of enterprise KM systems) will enable both autonomy/self-awareness and dynamic cooperation with partners and suppliers. Connectivity will be nearly total and speed of circulation of information will be much higher. Problem-solving capacities will enable self-healing and self-management in the hierarchically interconnected systems.

Intelligent enterprise should be able to create and maintain dynamic models of itself and its environment. The first model will be used to monitor internal operations and to maintain the key parameters in optimal range. The second model (external world-model) will reflect the state and change dynamics in the environment, passing variables and plans to the internal model for necessary adjustments. The more accurate these models are, the more efficient IE will be.

Here again, we may pose the question about the range of changes in analogy to nature-born systems: do we make small changes adjusting parameters to optimize certain behaviors or do we make the big, structural changes? For the reasons of longevity, both ranges should be necessary in order to adapt fully. So, small changes will adapt behaviors

to non-disruptive, stable situations, while big, structural changes are needed when we experience a one-of-the kind (tectonic), technology wave change.

Sources of the analogy for the modeling of IE evolution and improved understanding of potential future scenarios can be found in the theory and practice of complex, large-scale systems [4], biological systems [5], real-time systems [6] large autonomous computational systems [7][8], large social systems, business phenomenon [9], and large financial markets and systems.

Fifth Technology Wave : Darwinian Model

Making an analogy with natural systems, we may predict that the changes in business climate and environment will force advances toward the IE. Moreover, changes and repositioning in the value chains will force re-grouping and repositioning of entire industry sectors. Picturing future intelligent enterprises playing in different industry sectors, one may wonder what would be the time frame in which we may see their rise in a radically changed global market. This estimation might be based on the experiences from the previous technological waves as shown in Table 1 [*based on The Economist : A Crunch of Gears, September 22, 2001*]

Period	Technology
1780 - 1840 : 60 years - First Wave	cotton-spinning, iron making, steam power
1840 - 1900 : 60 years - Second Wave	steel making, railways
1900 - 1950 : 50 years - Third Wave	electrification, internal combustion engine
1950 - 1990 : 40 years - Fourth Wave	petrochemicals, electronics, computing, aerospace
1990 - 2020 : 30 years - Fifth Wave	corporate client-server networks, software, multimedia, telecom

Source : The Economist : September 22, 2001

Table 1 : Five Technology Waves - Last 200 Years

If we follow the evolution of the key technology waves in the last 200 years we may observe that all of them have had a very large and

widespread impact on which the cost-performance aspect of the entire industry sector was radically changed. It appears also that the typical gold-rush pattern was followed by the over-investments, shake-up and battles in which market leaders kill smaller competitors but then failed to achieve sufficient margins. This was typically followed by a steep and quick decline when investors redirected their attention to a new set of technologies. Key technologies survive for several generations, but the endeavor is no longer exciting or speculative. Important other players in the markets are financial enterprises, regulatory bodies, governments and stock exchanges. They influence strongly the pace and direction of developments and money flows. At the time of writing, it is not clear which combination of today's technologies will make this Fifth Technological Wave, as all key components are known but the winning combination that makes the IE possible is not yet discovered.

As we may observe a general contraction of the duration of each successive technology wave, we may postulate that the next 15-20 years might be the time horizon during which the new species of intelligent enterprises will rise, evolve and finally dominate.

This vision of the IE represents the magical and compelling challenge of creating large-scale artifacts that closely resemble nature-born living organisms -- very much like the Darwinian picture of the world in which species are created, evolved and morphed into better forms and superior organizations. Some of these species have disappeared and can only be seen today in museums. There is no reason that something similar may not happen to some contemporary enterprises. It seems that the lessons from Mother Nature should be studied carefully by scientists, technologists, business people and dream-driven futurists.

Acknowledgement

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