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Integration Architecture of Expert Systems, Neural Networks, Hypertext, and Multimedia can Provide Competitive Opportunities for Industrial Applications.

Edward L. Parkinson *, Max L. Hailey *, Ching F. Lo *, Bruce A. Whitehead *, George Z. Shi†, and George W. Garrison†

* The University of Tennessee Space Institute (UTSI), Tullahoma TN (USA)
† Center for Space Transportation and Applied Technology (CSTAR), Tullahoma TN (USA)

Abstract
This paper promotes the idea of integration of computer software technologies; such as, expert systems, neural networks, hypertext, multimedia, and graphics user interface (GUI), to an unique hybrid system that increase market opportunities and competitiveness. The goal is to present ingredients of a business strategy that can ensure the capability to provide long-term competitiveness for industrial applications. Concepts for development integration and flexibility, prototype system transferring, teaming, and other consideration for winning, evolving at The University of Tennessee Space Institute (UTSI) and the Center for Space and Applied Research (CSTAR), are presented to amplify on salient aspects of competitiveness.

Key Words: Expert Systems, Artificial Intelligence, Information Systems, Management Systems

1 Introduction

"Winning Strategies" - "Cooperation" - "Teaming" - "Commitment" - "Continuous Improvement" -- These are some of the ingredients necessary to be competitive in the global industry of today. One should be able to relate to these concepts whether being an established manufacturing concern, planning a new start, service industry, government agency, research laboratory, or university.

These precepts have also been the catalyst on why The University of Tennessee Space Institute (UTSI) has joined with the Center for Space Transportation and Applied Research (CSTAR) on a goal to "improve the competitive baseline by developing integrated software systems (hybrid knowledge-based systems) for industrial applications." -- A "Win-Win" strategy. The initial focus of this research, development, and partnership is in developing systems that integrate hypertext/hypermedia with expert system and other artificial intelligence technologies.

This paper first presents highlights of the initial systems developed by this team for the National Aeronautical Space Administration (NASA) and DoD. The approach, architecture, and experience with these systems will be "critically analyzed" relative to the objective of improving the long-term competitiveness. Strengths and weaknesses of the process are pointed out as "lessons learned." The importance to the improvement of the process is how these lessons are being incorporated into the present winning strategy and teaming efforts.

2 Assessment of Present Approach

The teaming and strategic approach that has been used by UTSI and CSTAR for research and technology development is perhaps similar to that used by most academia/research centers:

(1). Researchers within both organizations have mutual interests;

(2). Customer(s) and funding are sought to support technology development; and

(3). Some cost advantage and academia objectives are met by using graduate students to support technology development.

Researchers at the UTSI and CSTAR have had interests primarily in aerospace applications. Several research projects from the National Aeronautical Space Administration (NASA) and DoD have resulted various integrated knowledge systems and/or health monitoring systems:

(1). **Intelligent Hypertext Manual for Space Shuttle Hazardous Gas Detection System [1]**

This system assists the user in efficiently locating the applicable documentation and retrieves historical data. It helps the engineers in making quick and right decisions during the Shuttle launch. It can also be used for personnel training. This system is mainly a hypertext system with some intelligent for information retrieving.

(2). **SSME Anomaly Patterns Identification and Detection [2]**

This system is designed to post-analyze SSME ground test data to identifies patterns associated with anomalous SSME engine turbopump's behavior. It is more of a data processing system, but includes an expert system.

(3). Neural Network Based Expert System for Compressor Stall Monitoring [3]

This system was developed to help engineers in monitoring compressor stall by identifying patterns associated with compressor behavior. It consists of both neural networks and conventional data-analysis/pattern-recognition algorithm. This system also consists of a diagnostic expert system for analyzing the neural network output.

(4). Wind Tunnel Project Engineer's Intelligent Assistant [4]

This system was developed to aids wind tunnel project engineers in planning and conducting wind tunnel tests. It contains seven (7) engineering modules as well as hypertext documents related to NASA/ARC Unitary Facilities and wind tunnel testing.

Each of these systems consists of two or more off-the-shelf software packages, but is integrated into an unique system which has a friendly graphical user-interface and a set of system utility. These systems are all at different stages of technology transfer from a prototype system to a real word application.

On the surface, these projects appear to be winning developments because they met all project objectives and fulfilled all contract commitments. These projects also provided funding sources for technology development, development of a center of expertise, and supported the academia objectives. However, critical assessment of these projects provide, "lessons learned," can be used for improving the process of obtaining further funded research for this technology development, hence increase the competitiveness of the team in this field.

What will be the "true needs" of the system for using it in an operational environment? Have these requirements be adequately been considered in the development stage of product life-cycle development? Will there be too much resistance to the change brought by the new technology for the customers/operators to implement it? Will the reduction of government funding and a combination of the responses (cost/benefit/risks assessment) to the above make it where these projects have high risk of being rated as lower priority for further funding?

As with many technology development projects the answer was "yes." -- Then what are the lessons learned and what is our approach to improve funding for this technology thrust area? The remaining sections of this paper provide "salient features" of an improved strategic approach being implemented at UTSI/CSTAR.

3 Hybrid systems increase the flexibility of meeting customer operational requirements

Key concepts to improve competitiveness for the applications market include system design for "flexibility" and the "integration" of technologies to best meet the needs of the customer. Many researchers and entrepreneurs are approaching this basic idea from several directions [5, 6].

As indicated in Figure 1, when designing the internal performance of a system, one should be flexible in using a best combination of available technologies that provides the customers needs.

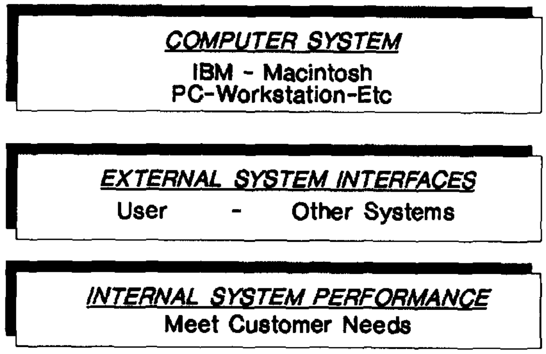

Figure 1. "Flexibility Needed" in Systems Development to Best Meet Customer Needs.

The external needs of the system should also be considered. Is it anticipated that the operational system will need friendly interfaces with the user, but will there be a need for real-time data input/processing or interference with other systems for real-time and efficiency in communication and control?

Is it wise to limit systems development to any one architecture? Should the potential developer insist on limiting system development to either a Macintosh or IBM architecture, or insist on the use of a mainframe?

From Figure 2, it is suggested that system design also consider the integration of architecture of technologies such as expert systems, artificial intelligence, hypertext and multimedia to provide competitive opportunities. For example, a basic hypertext application uses menus to interface with the user to identify which set of information is desired for review. This data could be text or graphics. While this architecture provides adequate support for many applications, what happens for applications when the customer realizes it is easier to use the existing management information systems than to input the data and keep the data current?

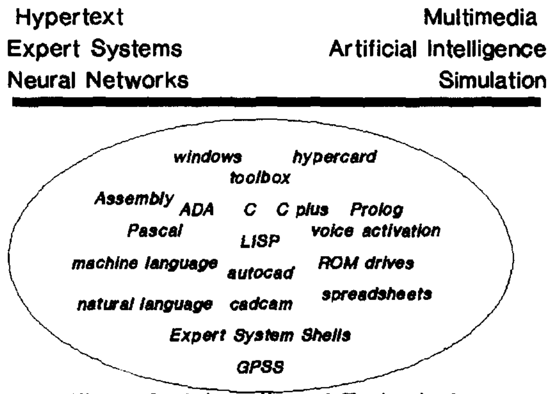

Figure 2. Integration of Technologies

In many cases, the customer uses the data to make decisions based on a limited set of decision rules. This could be presented in the form of classical expert system architecture. In other cases, however, the input data might be in a form that a neural network architecture is necessary and could be time saving. In another case, one could conceive of the input data driving a simulation model using some classical language such as General Purpose Simulation System (GPSS). Thus, added flexibility in architecture for integrating technologies; such as expert systems, neural networks, and GPSS, can provide more powerful capabilities to applications normally limited to one technology.

The same situation exists when the basic architecture and technology resolves around expert systems. Expert systems architecture can stand alone for many applications. However, what happens, when the customer has the need to gather information from other information sources for the expert system in order to provide the assistance needed? What happens when the input data varies and must be obtained from other analysis or data systems? What happens when after the expert assistance is provided, the customer then needs to take the information to basic drawings or to update with other management information systems? Thus, design with flexibility to integrate basic expert system architecture with other capabilities, such as hypertext or databases, may better meet customer needs. A similar scenario can be formulated when the basic systems approach is centered around a advanced technique of neural networks, embedded artificial intelligence.

What are the operational and competitive possibilities for education and training applications when the architecture of choice is multimedia? With current technologies, one quickly sees the opportunities for storing massive amounts of data on CD ROM disks and the use of video tapes and perhaps voice for more effective communication. However, what happens when one recognizes that the customer also needs interaction with an expert system or some other decision tools? Considering the applications for multimedia systems, will it be much more power if the systems includes expert system, embedded artificial intelligence techniques, and neural network processing techniques?

4 Transfer prototype systems to the real-world applications

Another very important aspect of the system development is transferring prototype systems to real-word applications. Particularly in academia, typical research work is targeted to advancing the technology base for a specific researcher area of interest, as opposed to developing and producing systems for real-world applications. New advances in learning, parallel processing, voice activation, vision, detection, natural language processing mechanism or expert system shell may be developed. Technology transfer usually occurs in the form of research papers or prototype systems.

Going from a prototype demonstrating advanced technology or operational system to the integration into an operational production system; however, usually requires significant impacts in cost and schedule, and in many cases changes the performance picture. In many cases, the real-world production systems require more functional area involvement, hence extensive development is needed to meet these customer needs. In some cases, prototypes are limited to the software portion of the total system requirement. Therefore, the production system might require extensive interface with other data systems or other hardware/software systems. In other cases, the prototype systems may not be feasible or practical for customers: the prototype may show concept feasibility, but the architecture is not robust, flexible, and reliable enough to handle the requirements of the applications. This can particularly be the case when using advanced technology and off-the-shelf software packages for prototype systems.

5 Other considerations to improve the competitiveness

The integration of technologies presents a significant point of strategy for competing in industrial applications. However, a best software architectural approach, within itself, does not ensure being able to compete for industrial applications. What then are other considerations for improving competitiveness? The following are a list of some other strategies to consider:

(1). **Target low risk developments and provide operational capability (production systems)**

Pick applications that have low development risks and have high return-on-investment potential to the customer. Implementing this strategy will improve skills in functional areas, improve the baseline for technology transfer, and provide funding sources for development of advanced technology. The low risk target markets can be operations, maintenance and logistics of systems or equipment, technical and operations support of functional areas, or education and training of personnel.

(2). **Encourage teaming, communication, cooperation and technology transfer among functional areas**

Typically the development of software systems are initiated and supported from one department or functional group. However, experience from systems development generically has shown a need to consider all phases of the product life cycle and the integration of all functional areas. There are many real-world applications that provide opportunities for competitive advantage if functional areas were a team versus separation. In academia, for example, one department might have expertise and man-power in developing computer software systems, while another department can provide the market (funding) in their technical area but lack programming capability. Either of the departments would probably fall short in getting funding or being able to either provide system development which will adequately meet customer needs. A team between these two departments will provide a perfect solution for both departments. In such cases, the flexibility provided by the hybrid systems will show its advantages.

At UTSI, these software systems were initiated through the aerospace and computer science areas. An expansion to other functional areas allows exploitation to other markets, thereby improving overall technology base development. In addition, teaming of functional areas with centers of expertise for system development allows the potential for improved "transition" of technology through the product life cycle.

Technical transfer from universities and centers of expertise to industry and other application areas is also very critical. It is very good to develop advanced technology, but it will be even better to apply this technology to real applications. This will also provide funding for further technology development. Again, the flexibility provided by the hybrid systems will show its advantages in meeting different requirements of the industry applications.

(3). Cost competitiveness and process improvement

Each of the factors identified in this paper provide potential for improving the competitive baseline. When taking all of these into consideration, one should be able to develop a business strategy that allows a significant range for competitively bidding projects. This paper does not go into depth with quantitative potential for cost competitiveness. However, as Figure 3 shows, choosing the right strategies can form the basis for improvement. Improvement can lead to further competitive opportunities and this flow can be viewed as a process for continued improvement.

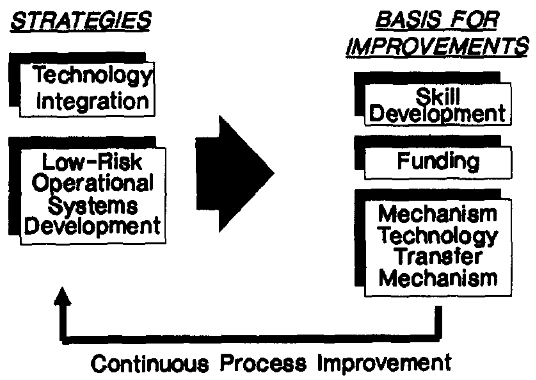

Figure 3. Continuous Process Improvement

6 Summary/Conclusions

This paper has emphasized a basic strategy of integrating computer technologies for system development; such as hypertext, multimedia, expert systems, and neural networks. The notion set forth is that the flexibility for tailoring the integration of technologies, can form an improved conceptual framework for developing operational systems, for long-term advances in technology, and form a natural basis for transition of advanced technology developments. This paper promotes teamwork among functional areas, and to target markets for low risk operational system developments to serve as a foundation for skill development and funding.

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