APPLICATION OF KNOWLEDGE BASED SYSTEMS TO VIRTUAL ORGANIZATIONS

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Abstract

Virtual organizations are networked organizations that bind together teams of people that meet and work together through the use of information technology. Such organizations may bring together hundred or perhaps thousands of separate organizational entities. Virtual organizations rely on and traffic in shared information so that the many entities they manage may coordinate their activities effectively and efficiently. Virtual enterprises supported by such organizations have the benefit of the shared expertise and resources of all the contributing members. In this paper, we discuss a prototype knowledge based system to advise companies considering the creation of or membership in a virtual organization.

1. Introduction

As technology evolves, new ways to organize and conduct group ventures present themselves. For instance, the advent of such appliances as the telephone and the fax machine enabled individuals to communicate and exchange information that hitherto required the use of face-to-face meetings and the postal service. Certainly, such issues as geographic distance and differing time zones lost some of their importance as technology began to weave individuals together into a communication's tapestry that could in moments disseminate information that previously took days or weeks to exchange. The advent of computer systems that could be linked with communications technology expanded the dimensions of this tapestry.

The ability to communicate electronically has enabled such organizations as businesses, universities, and scientific laboratories to exchange valuable information quickly and effectively. But the same technologies that revolutionized communication can also be used to restructure the very organizations that use them. Thus, organizations can, given the proper investment in technology, go "virtual."

Virtual organizations can be defined as "distributed organizations and teams of people that meet and work together on-line. Group members rely on support systems to help gather, retrieve, and share relevant knowledge" (O'Leary 1997). O'Leary et al. (1997) discusses the capabilities that virtual organizations can exploit, such as:

- the creation or assembly of productive resources quickly,
- the creation or assembly of productive resources frequently and concurrently, and,
- the creation or assembly of a broad range of productive resources.

A virtual organization can exist as an independent entity in its own right or be composed out of other organizations. For instance, ARPA's AIMS project attempted to create a virtual organization that linked companies such as Lockheed Martin, Texas Instruments, and Rockwell (O'Leary 1997). Each company still operated independently, but also shared resources and pursued specific manufacturing objectives through AIMS.

In this paper we will explore the feasibility of applying knowledge based system (KBS) technology to determining the information needs of organizations creating a virtual organization and suggesting the best strategy for accommodating those needs.

2. Virtual Membership

As computer systems have evolved, so has the technology that links these systems together. The existence of networking communications technology is instrumental to the creation and operation of virtual organizations. Such organizations rely on the ability to gather, retrieve and share relevant knowledge (O'Leary 1997). Without this capability, individuals in different locations, possibly working at different institutions, would be incapable of productive, cooperative, and coordinated work.

The technology to facilitate virtual organizations exists and has already been used for that purpose. Aerotech is but one example of a real virtual organization, built on top of available information sharing technology (Upton & McAfee 1996). The issue addressed in this paper is how to advise a company that using a virtual organization is in its best interest for pursing a particular product or service innovation.

2.1 The Three Stages of Determining V.O. Membership

Advising a company as to the wisdom of using a virtual organization can be viewed as a three stage process. In the first stage, the company must determine whether the innovation it wishes to pursue can be more efficiently and more effectively developed through a virtual organization. In stage two, the company must look at the relationships it shares with other firms to which it will be bound in the virtual organization developing the company's new innovation. Finally, in stage three the company must determine if its employees currently have the information technology skills and if its computing hardware and software have the capabilities to support the proposed innovation's development through a virtual organization.

2.1.1 Stage 1: Determining the Innovation Type

Chesbrough & Teece (1996) discusses two forms of innovation that companies may wish to pursue. *Autonomous innovations* can be realized without the need for concurrent innovations to be developed. For instance, a new flat top display for a portable computer could be developed and integrated into existing products without creating a new PC architecture. A new architecture, on the other hand, would be an example of a *systemic innovation*. Such an innovation requires complementary innovations in other, closely related areas (such as new chip designs and manufacturing techniques, more powerful batteries to drive the chips, etc.).

Chesbrough & Teece (1996) argue that virtual organizations are excellent engines in driving autonomous innovations. Such organizations "coordinate much of their business through the marketplace, where free agents come together to buy and sell one another's goods and services; thus virtual companies can harness the power of market forces to develop, manufacture, market, distribute, and support their offerings in ways that fully integrated companies can't duplicate." Systemic innovations require more centralized control of developing technologies and may even require the adoption of new industry standards. Such innovations are difficult to pursue through virtual organizations, where the very market forces that enable success in certain ventures make intensely coordinated activity difficult.

Using criteria gained from Chesbrough & Teece (1996) it was possible to extract twelve attributes to describe a proposed innovation. Six attributes apply to autonomous innovations and six to systemic innovations. These twelve attributes are represented in Table 1: Innovation Attributes.

Facts	Autonomous	Systemic
1	Component is a single entity in a larger system	Component is a composite entity
2	Component already exists in house, but needs improvement	Component doesn't exist in house; first time development
3	Process already exists in house to produce the component	Company has no in house process to produce the component
4	Component can be integrated into existing designs	Component requires new system designs for integration
5	Component can be produced based on existing industry standards	Industry standards don't exist for the component
6	Other companies already produce a similar component	Production methods must be invented industry-wide

Table 1: Innovation Attributes

Using these attributes, it is possible to describe a new innovation in terms of its autonomous and systemic qualities. Once an innovation is thus described, the kind of innovation being pursued can be determined by tallying the autonomous attributes and the systemic attributes. Consider an innovation I, attributes a_i and s_i where ($1 \le i \le 6$) and each attribute a_i and s_i is either 1 if the attribute applies to the innovation, 0 otherwise.

If $\Sigma_{i=1..6}\, a_i > \Sigma_{i=1..6}\, s_i$ then the innovation is considered autonomous. Otherwise, it is considered systemic. Systemic innovations are not appropriately pursued through virtual organizations. We use the above formula to accommodate mixed innovations that may have features of both autonomous and systemic innovations.

2.1.2 Stage 2: Determining the Nature of Company Relationships

Virtual organizations bind together companies that have agreed to coordinate activity based on shared information and resources. The extent to which these companies have agreed to collaborate (i.e., how much they are willing to share) determines the stage of their relationship. Upton & McAfee (1996) describe three stages, or degrees, of relationship that can exist between two companies. These stages of relationship are termed "dating," "engaged," and "married."

Using the criteria found in Upton & McAfee (1996), it is possible to deduce 8 different definitions of these relationship stages. In Table 2: Relationship Definitions, we show these 8 definitions and the relationship stages to which they are associated.

Dating Definition 1	Two companies are researching each other's business histories and practices.
Dating Definition 2	Two companies are exchanging bids and orders, but neither have accepted.
Dating Definition 3	Two companies have recently entered a customer/supplier relationship, but the quality of the relationship has yet to be determined.
Engaged Definition 1	Two companies have an established customer/supplier relationship.
Engaged Definition 2	Two companies are sharing manufacturing process information.
Married Definition 1	Two companies have visibly committed to a continuing relationship.
Married Definition 2	Two companies share data about production, inventory and schedules.
Married Definition 3	Two companies can access applications and information on each other's computers.

Table 2: Relationship Definitions

Using the above definitions, facts about a relationship can be used to infer that relationship's stage. For instance, if two companies share offices, then an inference can be made that associates this fact with "married definition 1" above, i.e. that the two companies have visibly committed to a continuing relationship. It is possible to consider any number of different relationship facts, as long as those facts can be related to one of the above definitions.

2.1.3 Stage 3: Determining In-House IT Sophistication

Many non-virtual companies have invested heavily in technologies that allow for electronic collaboration similar to that which occurs in virtual organizations. Such systems rely on technologies such as EDI, groupware and WAN's. However, none of these technologies can individually or in any combination fully facilitate a virtual organization (Upton & McAfee 1996). The reason lies in the role of a virtual organization within a network. A virtual organization has the unique responsibility of satisfying the information sharing needs of all possible member organizations. It is the virtual organization that coordinates and brokers the information that is used by its members. In doing so, the virtual organization must contend with specific factors involved in determining information sharing needs between member organizations. Technologies such as EDI, groupware and WAN's do not and cannot adequately address these factors.

Upton & McAfee (1996) represent a company's information technology sophistication by considering:

- The average level of computer expertise among company personnel,
- The highest level of computer expertise among company personnel,
- The type and power of installed hardware and software,
- The degree to which employees are already connected by an internal network.

Using the above considerations Upton & McAfee (1996) establish categories with which to represent a company's information technology (IT) sophistication. In this paper, the first two of the above considerations (i.e., average and highest level of computer expertise) are used to determine a company's IT expertise. IT expertise is, thus, a composite of these two considerations. Similarly, the other two considerations (i.e., the power of hardware/software and the connectivity of the internal network) form a composite that is used to determine a company's computing power capabilities. If the above four considerations are ranked (say, from 1 - 9), then the composites of these ranks yield the categories found in Table 3: IT Sophistication Levels.

Information Technology Expertise	**Capability of Computing Power**
Naïve	Simple Data Transmission
Knowledgeable	Shared Data Access
Expert	Telepresence/ Access to Applications

Table 3: IT Sophistication Levels

We define the above categories as follow:

Naïve	Company employees are not accustomed networked work groups or using remotely located application.
Knowledgeable	Company employees are accustomed to working in groups that electronically share data, but do not use remote applications.

Expert	Company employees can work electronically in groups and use networked applications remotely.
Simple Data Transmission	Company computers support simple data transfers, such as ftp.
Shared Data Access	Company computers can directly access shared data on other computers.
Telepresence/ Access to Applications	Company computers can support and use remote server applications.

Once again, the categories in Table 3 can be derived by using two composite ranking. One is derived from the average level of computer expertise among company personnel and the highest level of computer expertise among company personnel. The other is derived from the type and power of installed hardware and software and the degree to which employees are already connected by an internal network.

2.2 Role of a Virtual Organization

Upton & McAfee (1996) describe the three factors involved in determining information sharing needs that must be managed by a virtual organization. They are:

- Stage of relationship, determined in Stage 2 above,
- Lowest common denominator of information technology (IT) sophistication, determined in Stage 3 above,
- Level of functionality, determined in Stage 3 above.

These factors are represented in tabular format below in Table 4: Information Sharing Needs Considered.

Factor One	Factor Two	Factor Three
Dating	Naive	Data Transmission
Engaged	Knowledgeable	Shared Data Access
Married	Expert	Telepresence

Table 4: Information Sharing Needs Considered

A virtual organization should be able to integrate companies at any relationship stage, at any level of functionality and all but the most naïve IT users. To do so, the virtual organization must employ information sharing technology that can facilitate the interaction that results from any combination of the above factors. Technology that is capable of handling all combinations of factors is said to create an "information brokered inter-network" (Upton & McAfee 1996).

Thus, organizations that would like to "go virtual" must consider three aspects:

- Innovation to be pursued,
- The nature of all company relationships within the virtual organization,
- The sophistication of a company's use of information technology.

3. Knowledge Based System Application

The value of a KBS in this domain is that the decision to create or join a virtual organization can be very profitable or very costly to a company, depending on the innovation it is pursuing. We have constructed a prototype KBS that can be used as a virtual organization "advisor." The prototype is implemented in CLIPS 6.0[1]. There are 32 working memory templates and 65 rules. The KBS has three main tasks that are analogous to the membership categories discussed in Section 2. The process overview is presented in Figure 1.

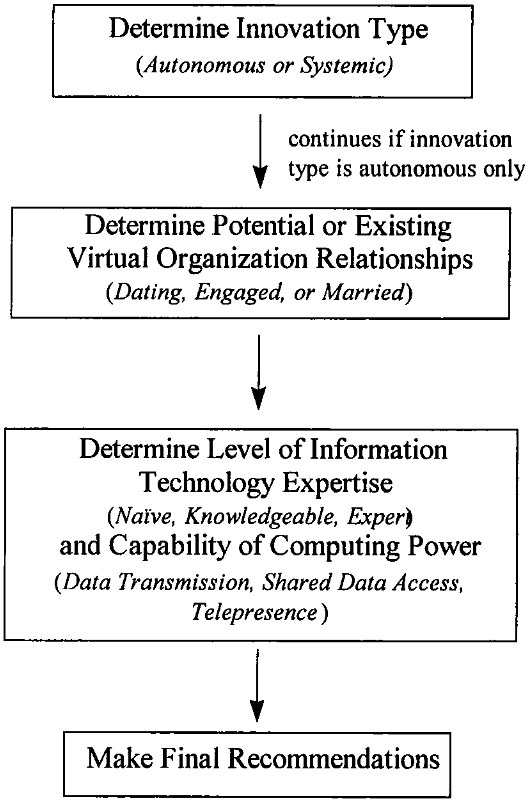

Figure 1: Tasks of KBS Virtual Organization Advisor

[1] CLIPS is distributed by COSMIC, University of Georga, Athens, GA.

3.1 Determining the Innovation Type

The first task in Figure 1 determines if the user's company requests an innovation type of Autonomous or Systemic. The user enters facts according to the criteria discussed in Section 2. The knowledge base simply counts how many of the criteria are satisfied. If there is a clear majority criteria satisfying one innovation type over the other, the system makes the choice in favor of the majority. In the event of no clear majority, the KBS responds with a Systemic innovation type.

3.2 Determining the Virtual Organization Relationships

The second task in Figure 1 determines the *dating, engaged,* or *married* relationships between the user's company and the other prospective companies in the virtual organization. A template is constructed for each of 17 attributes that help to determine the relationship according to the definitions for dating, engaged, and married discussed in Section 2. Upton & McAfee (1996), Davidow & Malone (1992) and Konsynski & McFarlan (1990) were used to develop these 17 attribute templates. The user can assert one or more attribute templates for each firm with which her/his company will be bound in the virtual organization. Table 5 shows the attributes and to which relationship definition a TRUE value for the attribute corresponds.

Attribute	Relationship Definition
Exchanging information about products and services	Dating 1
Request and receive bids and quotes from each other	Dating 2
Currently establishing contracts and purchase orders	Dating 3
Other firm is established supplier	Engaged 1
Other firm is established customer	Engaged 1
Cross-license patents	Engaged 2
Shared cost information	Engaged 2
Shared joint design of data definitions and formats	Engaged 2
Shared long range planning	Married 1
Involved in a consortium	Married 1
Established conflict resolution strategy	Married 1
Shared office	Married 1
Shared "common vision"	Married 1
Joint research conducted	Married 2
Electronic interchange agreement	Married 2
Shared common database	Married 3
Shared remote computer usage	Married 3

Table 5: Templates for Relationship Attributes

Templates are constructed for each company in the prospective virtual organization in order to establish a tree of relationship types, in which the root is the user's company. The KBS processes the information and constructs the tree. Though this information is maintained, generally, it is the highest level of relationship that is important in the final recommendation.

3.3 Determining Information Technology Expertise and Computing Power

For this task, the user supplies a set of rankings for the company that correspond to the following criteria:

- Average computer expertise
- Highest level of computer expertise
- Computing power
- Current network connectivity

Initially, we allowed for a range of 1..9 per criteria. However, the knowledge accumulated for determining the level of information technology expertise and the level of computing power focused on only a three-level ranking. The rules take a composite of the rankings of criteria 1 and 2 to determine if the information technology expertise is *naïve, knowledgeable,* or *expert.* In the same manner, a composite of the rankings of criteria 3 and 4 determine if the capability of the computing power is *data transmission, shared access,* or *telepresence.* The KBS rules are generic to allow for additional criteria, rankings, and more granularity of conclusions.

3.4 KBS Recommendation

Once the system has determined the highest relationship stage to be managed by the virtual organization, the user's company's information technology expertise and the user's company's computing power capability, the KBS makes a recommendation to the user. It infers whether the user's company can create with existing expertise and equipment a virtual organization to accommodate all of the company's relationships. If the company is deficient in expertise or equipment, the KBS informs the user of the deficiency, indicates where the deficiency lies, and indicates that a virtual organization can not currently be created by the user's company.

4. Conclusion

In this paper, we discussed the knowledge engineering aspects of creating a prototype KBS application that analyzes and advises on virtual organization membership and structure. The system determines, given a company's innovation goals, whether a virtual enterprise is advisable for the effective and efficient pursuit of those goals. The system determines the stage of all relationships with which the company will be bound in the virtual organization. The system further determines the level of information technology sophistication of the user's company. If the organization can appropriately create its own information brokered inter-network, the system makes that recommendation. Otherwise, the system notes deficiencies at the company that prevent it from constructing the network, and thus creating an organization that can manage all of the company's virtual relationships in pursuit of a new innovation.

The design of a KBS to act as a "virtual organization advisor" experienced several difficulties. For example, the state of knowledge on developing an information brokered inter-network has not yet been codified. The management of a virtual organization could feasibly involve thousands of individual companies, all of which must be integrated using existing technology. Current research in AI and virtual organizations continues to investigate the means to accomplish such integration (O'Leary et al. 1997). Since many new techniques are still being researched and current techniques may be proprietary information, capturing such knowledge proved difficult in the knowledge engineering stage of KBS development.

Additionally, the KBS developed is not particularly user friendly. The user must supply a good deal of information to the system in a specified format for any analysis to take place. Instructions would need to be provided to the user in order for the user to provide attribute values or rankings. As virtual organizations mature and more studies of the mechanisms by which virtual organizations are constructed and managed are conducted, additional information for knowledge engineering will be available. The lack of such information and "expertise" limits the robustness of any knowledge based system. However, we conclude that there is a place for this type of system.

References

(Chesbrough & Teece 1996)
Chesbrough, Henry W.; and Teece, David J. When is Virtual Virtuous? *Harvard Business Review*, January-February 1996: 65-73.

(Davidow & Malone 1992)
Davidow, William H. and Malone, Michael S. 1992. The Virtual Corporation. New York: Harper Collins.

(Hedberg 1995)
Hedberg, Sara Reese. Intelligent Agents: The First Harvest of Softbots Looks Promising. *IEEE Expert* August 1995: 6-9.

(Konsynski & McFarlan 1990)
Konsynski, Benn R.; and McFarlan, F. Warren. Information Partnerships - Shared Data, Shared Scale. *Harvard Business Review* Sept.-Oct. 1990: 114-120.

(O'Leary 1997)
O'Leary, Daniel E. The Internet, Intranets, and the AI Renaissance. *Computer* January 1997: 71-78.

(O'Leary et al. 1997)
O'Leary, Daniel E.; Kuokka, Daniel; and Plant, Robert. Artificial Intelligence and Virtual Organizations. *Communications of the ACM* January 1997: 52-59.

(Pape 1995)
Pape, William R. Becoming a Virtual Company. 1995. *Inc. Technology*. 4: 29-31.

(Upton & McAfee 1996)
Upton, David M.; and McAfee, Andrew. The Real Virtual Factory. *Harvard Business Review* July-August 1996: 123-133.