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MODELING STRATEGIC NETWORKING USING ANT COLONY OPTIMIZATION TECHNIQUES

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Abstract

This paper presents research in progress to model the networking of small to medium sized enterprises (SMEs) as they search for and attain resources from external sources, such as government programs. The model is developed using Ant Colony Optimization (ACO) techniques which are based on observed ant behavior. Discussed is an Ant System (AS) model which illustrates a single colony of artificial ants, representing the SME, in search of and establishing a network of sources in optimal time. The returns from each source contribute to the net worth of the colony. Future research will develop this AS by implementing competition through parallel processing techniques. In addition, introduced into the AS will be the concept of obstacles and pointers which businesses use to redirect resource efforts. The ACO methodology can be used in the development of mechanisms for the allocation, distribution, and placement of resources available for organizational use.

Introduction

Small to medium sized enterprises (SMEs) do not always make use of available external resources. The United Kingdom government in conjunction with local Universities, government offices, and professional organizations offers various resources to the SMEs. In the South West of England, the government sponsors a number of programs through the University of Plymouth. These programs offer financial assistance by subsidizing staff salaries; education by holding training courses or seminars; and intellectual resources by facilitating access to faculty with specific technical skills and knowledge. In addition the Ministry of Agriculture offers programs to local businesses in their field. SMEs find out about these resources through direct mailings, advertising, word-of-mouth, etc. and some take advantage of what is available. The resources are limited and the more participants involved, the less that is potentially available for each. Some programs are available for a short time only and when finished new resources must be sought. Resources are usually available over a network instead of a single point and understanding how resources are acquired and accessed in a network will enable providers to better facilitate channels of delivery.

A network of firms describes any set of informal relationships between value creating agents and these are characterized by the co-operation and interdependence between participants. Studies of networks of organizations indicate the importance of network relationships to firms' accumulation of assets and the achievement of their strategic goals. The Chetty and Blankenburg Holm (2000) study of the internationalization of SMEs confirms the effectiveness of networks. This paper will introduce the research in progress in modeling the SMEs' search for available resources, i.e. the building of strategic networks, through the use of Ant Colony Optimization (ACO) techniques.

Using the case study methodology this research uses detailed analysis of companies to find common patterns of strategic behavior. (Yin 1989, Eisenhardt 1989) This is a longitudinal analysis of SMEs in the South West of Britain. Firms were chosen because of their existing links to the University of Plymouth which indicated they were already network players and because the firms exhibited contrasting approaches to networking. A detailed store of information on the company over a minimum two year period was already available and this was supplemented by interviews with key decision makers in the companies and with their academic contacts. Data was sought on the number and type of linkages the firm had, how the links had been initiated, how they were maintained, and what links kinds of links had failed and the reasons why they had failed. Of interest were the accumulation of contacts and whether contacts overlapped in terms of their resource acquisition potential. Finally noted was the perceived success or otherwise of the link measured in terms of profitability, sales, market share of the networks.

The process of strategic networking of SMEs for available resources correlates with the ant colonies behavior in acquiring and accessing food resources for survival. SMEs can not live in a vacuum, in order to survive they must be create business opportunities. This is the equivalent to the ant's search for food. As a food source is discovered, the ants will continue to use that source until it is depleted for whatever reason. Ants do not rely on one source, similar to most SMEs multiple sources are sought and used. However, in the ant world, as in the SME, there exist other ant colonies (SMEs) in search of and competing for resources, and attempting to take their share of those found. The results of the case studies will be used to evaluate the ACO technique.

The basis for ACO techniques is the behavior of ants in optimizing the acquisition and access of resources. Ants are known as social insects in that they live in colonies, and the survival of the colony, as opposed to individual survival, is of utmost importance. The ants' search for food is of special interest since, as ant researchers have noted, ants manage to find the shortest path between the colony and a food source (Dorigo et al. 1996). Although ants are almost blind they are able to find and return to a food source by depositing a substance called pheromone as they travel. This material serves as a marker to other ants who will follow the pheromone trail to the food source, as well as marking the route for ants to return again and again to this source. While most ants follow the trail to a particular food source, other ants continue searching for additional sources of food. This enables the colony to have multiple food sources in the event that one or more sources become depleted.

Based on the behavior exhibited in real ant colonies, ACO algorithms mimic the actions taken by ants in their search for food. ACO has been used to solve a number of NP-hard combinatorial problems such as the traveling salesman problem (Dorigo et al. 1999), full truckload transportation problem (Doerner et al. 2001) and in the telecommunications field for load balancing (Schoonderwoerd et al. 1997; Di Caro and Dorigo 1997). Dorigo et al. (1996), one of the first to use ACO, takes three ideas from the natural ant world and uses these for the basis of the artificial ants' behavior: (1) the likelihood of selection of a path with a higher pheromone content; (2) the increased deposit of pheromone on the shortest path; and (3) communication among ants on the trail. In Dorigo et al. (1996) application of the ACO to the traveling salesman problem, the artificial ants were given properties not available to real ants: limited sight; memory; and a discrete time environment. The work described in this paper will adopt features suggested by Dorigo et al. (1996).

Equivalent to the real ant nest is the home location in the artificial Ant System (AS) (figure 1). All ants are involved in the building of the network. In this model, an AS population of five artificial ants begins at the home base and each searches randomly for resources leaving a trail as it travels. After the first few moves, the ants are spread out in a random fashion, each with a trail. However, since initially none of the ants has discovered a source their trails are not strong enough to attract the other ants. Later on, as an ant discovers a source, its trail will have a stronger attraction to the other ants. The ants use a hill climbing/tabu list technique combined with a Monte Carlo method to optimize their next move. For instance, if an ant is at an intersection that has been crossed by ants bearing food, there is a good chance it may follow the direction with the highest level of pheromone (most usage), but it will not use its own previously discovered unsuccessful trails. This means that an ant may or may not select the quickest route to the source but chances are good that it will. If there is no trail to assist in the decision making process, the choice of direction will be random.

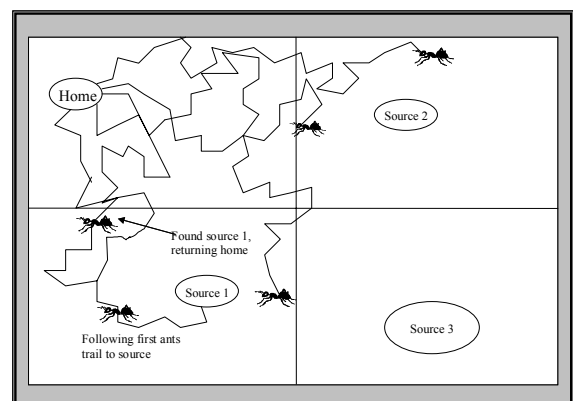


Figure 1. The Ant System After One Ant has Found the Source

Over time more ants will discover the route and return to the nest with the available resources. Each source has data associated with it such as money, free educational benefits, access to technical assistance, all of which is brought home increasing its net worth. The better the source the better value, if a source is over subscribed the return will reduce and this will indicate to the colony they should look more vigorously for a new source. The resources are distributed as a percentage of the amount available to the number visiting. The final state of the AS shows the discovery of all the resources and the ants continuing to optimize their net worth from all available sources and by the quickest routes but focusing their energies on those sources with the most to give. As neither the ant colony nor the business world exist as a single entity, colonies or businesses may compete for the same resource. To investigate this scenario, a parallel AS will be used which has a number of colonies all vying for the same resources and competing against one another to achieve this goal. This will simulate the manner in which SMEs acquire networks of resources, use them, keep them on hold, and reject them to their benefit. Parallel modeling can be computationally intensive, and future work will utilize the techniques adopted by Bullnheimer et al. (1997) who investigated synchronous parallelism strategies for ant colonies.

In addition to parallelism, the concept of obstacles and pointers will be introduced. Research by Dorigo et al. (1996) illustrates that ants, when faced with an obstacle, react by working around it. Similar obstacles may exist to an SME, for instance, the removal of a vital contact, new official requirements or policy changes, all of which can lead to a set-back, and prevent access to resources. Further, there may be requirements about the order in which sources are used. For example, source two must be visited before source one and this can lead to a source path being dormant until the other source has been discovered. On the other hand, SMEs may get pointers to these sources, through referrals, contacts made on the golf course or gym for instance, mass mailings, or newspaper or professional journal articles. In the AS these pointers should be placed to give directions to the ants. This is analogous to a real ant 'smelling' a picnic. An ant that was wandering randomly will have more impetus to choose a particular direction and this could potentially lead them more quickly towards a source by focusing this wandering.

The principles underlying an AS and ACO are simple in concept. However, these principles are powerful in use. The AS shows much promise as a viable technique for simulating the use and acquisition of resources by an organization for survival. The popularity of the ACO technique underscores the value of its potential. The ACO methodology can be used in the development of mechanisms for the allocation, distribution and placement of resources available for organizational use. While the accumulation of the right resources is clearly critical to a firm's competitive advantage, so is the order in which they were accumulated. The accumulation of both tangible and intangible resources is path dependent (Penrose 1959) and the nature of their accumulated, fixed capital, liquid assets, and intangible, knowledge-based assets, determines their ability to develop new resources and capabilities or assets in the future. This research focused on a single company searching for multiple resources. In later research, competition will be introduced and modeled with a parallel version of the ACO algorithm.

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