Intelligent Agent Framework for Modelling the Evolution of Small and Medium Sized Enterprises

Karen Blackmore
School of IT,
Charles Sturt University
Bathurst, NSW, Australia
kblackmore@csu.edu.au

Terry Bossomaier
School of IT,
Charles Sturt University
Bathurst, NSW, Australia
tbossomaier@csu.edu.au

Denise Jarratt
School of Marketing & Mgt,
Charles Sturt University
Bathurst, NSW, Australia
djarratt@csu.edu.au

Keith Nesbitt
School of IT,
Charles Sturt University
Bathurst, NSW, Australia
knesbitt@csu.edu.au

Abstract

Small and medium sized enterprises constitute a major component of the Australian economy. In fact in 2000-2001 they accounted for up to 91% of all businesses and provided 80% of all private sector employment [1]. Therefore many service industries are interested in the growth and potential of the small and medium business sector. However, modelling these enterprises is difficult because of their small size, and individual natures. One largely untried approach is to use agent-based modelling. Agent frameworks have become a powerful tool for modelling complex, interacting systems. This is a result of an agent-based systems capacity to handle nonlinear systems, their inherent flexibility and their ability to learn and adapt as the model evolves.

INTRODUCTION

The importance of small and medium sized enterprises (SMEs) to local, national and global economies is well understood. This is illustrated by the increasing amount of research aimed at understanding aspects of *organisational change* within the SME business sector [2, 3]. In particular this research studies the process of growth and innovation that an enterprise experiences as it evolves over time.

High-Level View

The agent framework presented in this paper focuses on the strategic behaviour of SMEs and the implications of different behaviour types, represented by a fuzzy logic ruleset, to information flows. This research is not an economic pricing model, rather, it is part of a larger project which aims to improve customer relationship management (CRM) practices by enabling more integrated marketing research and improving data mining practices within organisations servicing the SME sector. To this end, customer data on SMEs and measures of the economic environment form the two principle inputs to the over-arching agent-based system (figure 1). These data sources reflect the accent on customer relationships and the fact that SMEs are influenced by economic changes [4, 5]. The current agent-based framework model represents a component part of this over-arching framework. The framework will be extended to utilise commonly captured customer demographic data (about SMEs) that is often available in organisational data warehouses. The environmental condition indicators are also publicly available measures. Of course in the future, one might envision extending our agent-based framework so that mobile "information agents" proactively seek out their own data from electronic sources. However, currently the main agents we have modelled are SME-Agents. SME-Agents are designed to capture the concept, i.e., the needs and the behaviours of SMEs.

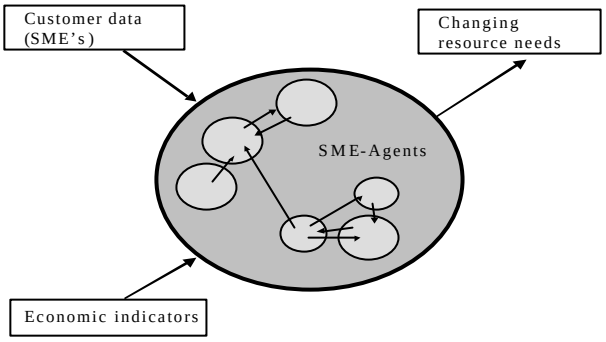

Figure 1. A high-level view of the agent system.

Current Model

As in the real-world, different SME-Agents have different beliefs, desires and intentions. Different businesses adopt different strategies of growth or survival. Some businesses operate in competition, while others may collaborate. SMEs consider not only broad environmental impacts, but also local spatialised competition and demands. For example, a local business may find it difficult to grow beyond its existing customer base. Perhaps, similar businesses may find themselves in direct competition if they are too closely situated. While the need to include spatial interaction is acknowledged, the inclusion of these dynamics will be left for future work.

A key success factor for businesses is the ability to align resources and strategies to changing environments. For example, computer or telecommunication needs change as a result of both environmental factors and the company's changing state in that environment. Importantly, a business may need to also change in response to customer needs. Our agent-based model is designed to allow for exploration of the role strategy and changing customer demands play in the telecommunications needs of an SME. The end goal is to predict changes in the resource needs of SMEs that result from change in the way a business employs strategies to compete under changing environmental conditions and customer demands.

STRATEGIC BEHAVIOUR

In today's business environment (exhibiting changing technology, economy, industry structure and participants, demand and supply), the barriers of economies of scale, differentiation, switching costs and distribution access have become obsolete. Consequently, strategy frameworks that address the fleeting nature of competitive advantage are argued to play a more dominant role [6]. The development of core competencies and capabilities, and strategies drawing on these resources, will be driven by the desired attainment of a future position. This presupposes that senior managers have a view about the future and, that their view is shaped through understanding all the relevant and appropriate developments that will drive the future. More particularly, it implies that their decisions will be shaped by a mental model that results in a consistent pattern of decision making.

Miles and Snow's Typology

Miles and Snow [7] described an organisational strategic orientation theoretical framework, based on the consistency of management decision patterns. This framework was subsequently validated across a breadth of domains, from health care markets [8] to electronic manufacturing [9]. Therefore this framework is adopted in our model as it also provides an appropriate segmentation basis to study resource change decisions.

Miles and Snow [7] define four categories, defender, prospectors, analysers and reactors. The typology views organisational patterns of strategic behaviour as an 'adaptive cycle', characterising behaviour using three strategic 'problem and solution' sets: (1) entrepreneurial problems focussing on the product-market domain; (2) engineering problems centring on the choice of technologies; and (3) administrative problems involving structure and processes. Each of the three problem sets involve multiple dimensions with a total of eleven distinctive strategic dimensions used to characterise the defender, analyser, prospector and reactor strategic types. Prospectors have been demonstrated to emphasise technology leadership, invest heavily in technology and exploit new product and market opportunities. Defenders, on the other hand are conservative, only investing in proven technology directly related to their line of business, producing a constrained product range for a narrowly defined market. Analysers are only willing to invest in new technologies following a detailed investigation of the issues surrounding its application and benefits, while Reactors are characterised by extreme organisational inertia [21, 12, 8]. These distinct behavioural orientations are argued to shape resource change decisions of managers as they respond to information on changes that occur in the economy, technology, industry structure, supply and demand.

Strategies define the purpose of organisations, the competitive domain of firms and the resource commitment these organisations make to achieve and sustain competitive advantage [12, 13, 14]. Hence, developing an appropriate strategy that fits the marketplace is one necessary ingredient for business success, which according to Miles and Snow, is 'achieving fit' between the firm and its environment. In operationalising the business strategy concept, Miles and Snow [7], Porter [15] and Miller and Friesen [16] as well as other researchers have done much in developing empirical and conceptual typologies of strategies. The typology as proposed by Miles and Snow remains one of the most popular approaches for defining and measuring the effectiveness of business level strategy [17]. It has been debated and supported by many researchers over the years [18, 19, 20, 17]. These studies have contributed significantly to the body of knowledge on strategic archetypes. The Miles and Snow typology has been demonstrated to predict 24% of the variance in overall organisational effectiveness [10]. Furthermore, the behavioural categories of this typology have been aligned with strategic aspects of product and service innovation and the degree and nature of market focus [11].

MODELLING AN SME AGENT

Holland [22] describes a complex adaptive system as an "*evolving perpetually novel world where there are many niches with no universal optimum of competitor, where innovation is a regular feature and equilibrium rare and temporary and where anticipations change the course of the system, even when they are not realized*". This description also seems well suited to describing a population of SMEs.

SMEs can also be conceptualised to fit John Casti's working definition of a complex adaptive system [23], comprising a population of "individual agents" who adapt their rules of behaviour over time. This could be interpreted to apply to a population of SMEs or the individuals who comprise them. If descriptions of SMEs are analogous to a complex adaptive system, then it follows that complexity theory may provide an understanding of the dynamic behaviour of SMEs, and assist in predicting changes in individual or populations of SMEs.

SMEs are not a homogeneous population, they vary considerably in size and sector activity, in their ownership, their location and the markets served. Some of the features of their domain are commonly shared, such as interaction with key economic stakeholders, such as banks and government agencies. Businesses operate in a regulated environment, providing at least some of the "rules" of behaviour. Financial resources represent the exogenous "energy", without which activities usually cease. Other resources, such as human and information and communications technology (ICT), are also requirements for operation.

One contribution that complexity theory makes to SME and entrepreneurship research is that it provides for multi-level views of both individual and populations of SMEs. It also provides concepts for making sense of changing patterns in the data. The notions of emergence, bifurcation and symmetry breaking in complexity are all notions of the "natural" formation of structures that behave with

different characteristics from the agents that constitute the structures. This may provide general propositions for why SMEs do not behave exactly like their owners.

It is suggested that the analogy of a complex adaptive system can provide a conceptual framework to understand or illuminate the dynamics of SMEs because:

i. Each business is different
ii. Each has its own "initial conditions" and each incurs a number of "events" in their temporal path.
iii. Given that entrepreneurs are "innovative", then many businesses will operate with their own "rules", as well as complying (more or less) to more general rules. There is a great deal of "replication" in the population as one SME copies another's ideas and government policy encourages SMEs to adopt "best practice".

The agent framework presented in the following section is a step toward a dynamic, multi-level analysis of SMEs at both the individual and population levels. By bringing together empirically validated rules of strategic behaviour typologies in a simulation environment, variations in emergent performance and communication flow can be analysed given differing levels of strategy types and consumer demands.

OVERVIEW OF THE AGENT FRAMEWORK

One of the objectives of this paper is to determine the minimum agent framework required to give rise to the Miles and Snow typology. In order to assess the validity of a fuzzy ruleset against Miles and Snow's strategic typology, a simple agent-based system (Figure 2) was constructed. In this system, SME-Agents operate in an artificial market place using fuzzy behaviour rules based on a subset of dimensions characterised by Defender, Analyser, Prospector and Reactor (DAPR) strategy types.

The model considers a retail scenario, where products are bought by SME-Agents for sale to consumers. The model accounts for only Business to Consumer (B2C) transactions and not Business to Business (B2B) and is parametrised using a chromosone like model (8 bits per parameter). The behaviour of SME-Agents is determined by using a fuzzy logic ruleset, which is discussed in detail in the following section.

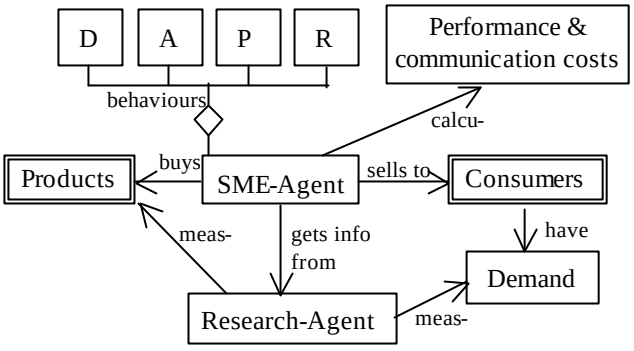

Figure 2. Agent framework with SME-Agents behaviour rules from Miles and Snow's strategic typology.

At each time step, SME-Agents decide whether to obtain customer demand information, how much of which products to buy. The model uses a pure data-push model, that is, consumers are presented with a full product list from which to select from. Changing products and obtaining demand information involve information flow, which is measured and tracked in the SME-Agent's state. A simple measure of SME-Agent performance, calculated by subtracting the amount spent on product from the amount received from sales to consumers, is also maintained in the agent's state.

SME-Agent Behaviour and Performance

The Miles and Snow four strategic types are employed to define the behavioural parameters of SME-Agents. Only the entrepreneurial problems and solutions adaptive cycle component was considered in this framework. This is a valid simplification as the current model focuses only on SME-Agent engagement with products and consumers. The behavioural parameters we model are:

i. Agressiveness (high, medium, low)
ii. ProductMix (high, medium, low)
iii. Awareness (high, medium, low)

SME-Agents maintain state parameters to be used for decision-making. These parameters consist of:

i. Cash level
ii. Stock ID
iii. Stock level
iv. Product longevity
v. Profits from last sale
vi. Average profit, and a
vii. Information flow measure.

A stock ID, level and longevity parameter is maintained for each type of product purchased by an SME-Agent for sale to consumers. The longevity parameter is incremented each iteration of the simulation to indicate the amount of time that an SME-Agent trades in a particular stock item. All trading costs are associated with an information flow.

Products

A simple product set is proposed, which are not agents, and at each time-step SME-Agents purchase one or a number of different products to sell to consumers. SME-Agents are initialised with equal financial resources to purchase products. Products are described using the following parameters:

i. ID
ii. Type
iii. Quality
iv. Cost per unit
v. Cost of entry

Consumer Demand and Growth/Decay

At the beginning of the simulation, the consumer set is initialised with equal demand in all product areas. Consumers are minimal agents with no adaptive behaviour and preferences are recorded using the following parameters:

i. ID
ii. product
iii. quality
iv. price
v. conservatism

In order for an SME-Agent to complete a sale, only the product preference of a consumer is fixed. A perfect match between the quality and price of products for sale and a consumers preferences is sought, however, an "acceptable tolerance" will allow consumers to purchase products closest to their preferences. Consumers are allowed buy requests until satisfied.

The consumer demand in the product areas will vary over time. This will enable a number of simulations using different consumer environment situations to be considered, namely:

1. Static
   In this scenario, consumer demand is fixed.
2. Turbulent
   A random replacement strategy is used to create a turbulent consumer environment. Once a consumer has made a successful purchase from an SME-Agent, the consumer are deleted from the set and randomly replaced.
3. Fashion/trend
   Trends in consumer demand are modelled using a growth and decay strategy. Each time a customer makes a successful purchase that customer will be deleted and replaced with a mutation. Thus the level of customers in the model remains constant, however, the types, quality and price of products they are willing buy vary in a trending scenario.

The conservatism parameter captures the preference a consumer has for buying products from an SME-Agent with longevity in a particular product. For example, a highly conservative consumer has a preference toward SME-Agents who have been selling the product of interest for the greatest amount of time, as measured by the stock longevity parameter. Conservativeness is measured as high, medium or low. High conservatism indicates that a consumer will rank by longevity then price, medium ranks by price followed by longevity, and low considers only price irrespective of longevity. In all situations, consumers will consider quality as the third ranking criteria by which to select SME-Agents to purchase products from.

Other Agents

The Research-Agent maintains information on consumer demands and changing trends. The Research-Agent maintains:

i. List of consumers and current preferences
ii. History of consumers and preferences

SME-Agents decide whether to poll the Research-Agent for information on consumer demands based on their behavioural rules. Obtaining information from the Research-Agent involves a communication flow and incurs a financial cost, the amounts of which are dependant on the type of information requested by an SME-Agent. The communication flow measure resulting from an information request is maintained in each SME-Agents state.

Fuzzy Logic Ruleset for SME-Agents

Through the use of fuzzy logic, rules can be organised and written to address the uncertainty and imprecision of business strategic decisions.

Decisions

Decisions are made based on the behaviour rules of SME-Agents and result in differentiations in information flows and profits. The outputs of defuzzification are crisp and relate to the following decisions:

i. ProductMix (add, delete)
ii. Buy (more, less)
iii. Research (getInfo, noInfo)

At various stages throughout the simulation, SME-Agents will make decisions about whether to add or delete products from their product mix, whether to buy more or less products in their chosen product mix and whether to buy research information about customers.

Rules of Engagement

The fuzzy rules aim to reproduce the Miles and Snow typologies. SME-Agents will evaluate the rules in the context of the current product mix, customer demand information and profits from previous sales. The following outlines the fuzzy ruleset and the implied strategy types.

Information

If Awareness = High THEN Research = getInfo ? Prospector

If ProductMix ? Low AND Awareness = Medium THEN Research = getInfo WHEN any profits < Avg ? Analyser

If ProductMix = Low AND Awareness = Medium THEN Research = getInfo WHEN any profits < Avg ? Defender

If Awareness = Low THEN Research = getInfo WHEN all profits < Avg ? Reactor

Buying and ProductMix

If Agressiveness = High AND ProductMix = Low THEN Buy = more WHEN profits >= Avg ? Defender

If Agressiveness = High AND ProductMix = Low THEN Buy = less WHEN profits < Avg AND customer demand >= Avg ? Defender

If Agressiveness = High AND ProductMix = Low THEN ProductMix = Add WHEN profits < Avg AND customer demand < Avg ? Defender

If Agressiveness ? Low AND ProductMix = High THEN ProductMix = add AND Buy = more WHEN profits >= Avg ? Prospector

If Agressiveness ? Low AND ProductMix = High THEN ProductMix = add AND Buy = less WHEN any profits <= Avg ? Prospector

If Agressiveness ? Low AND ProductMix = High THEN ProductMix = add AND ProductMix = Delete WHEN all profits <= Avg AND consumer demand < Avg ? Prospector

If Agressiveness ? Low AND ProductMix = Medium THEN Buy = more WHEN Profits >= Avg ? Analyser

If Agressiveness = Low AND ProductMix = Medium THEN ProductMix = add AND Buy = more WHEN profits >= Avg ? Reactor

If Agressiveness = Low AND ProductMix = Medium THEN ProductMix = delete AND Buy = less WHEN profits < Avg ? Reactor

The Miles and Snow typology differentiates strategies along the aggression, product mix and research dimensions, which are reflected in the fuzzy ruleset. Defenders are characterised by a narrow and carefully focussed product-market domain, which they aggressively defend. They exhibit prominence in their product market(s) and cautiously monitor activity in their domain. Prospectors can be conceptualised along an opposing axis to defenders (Figure 3). They are characterised by a broad and continuously expanding product-market domain, in which they are active initiators of change. They aggressively search for new opportunities. Analysers exhibit a mixture of both the defender and prospector behaviours. Analysers are characterised by a segmented and carefully adjusted product-market domain, maintaining core product(s) whilst "prospecting" in others. They are calculated followers of change and employ competitively oriented and thorough surveillance. Conventionally, reactors have been presented as a 'residual' type, lacking consistent characteristics. They exhibit uneven and transient product-market domain behaviour, characterised by opportunistic thrusts and coping postures. Reactors employ only sporadic and issue dominated surveillance [7].

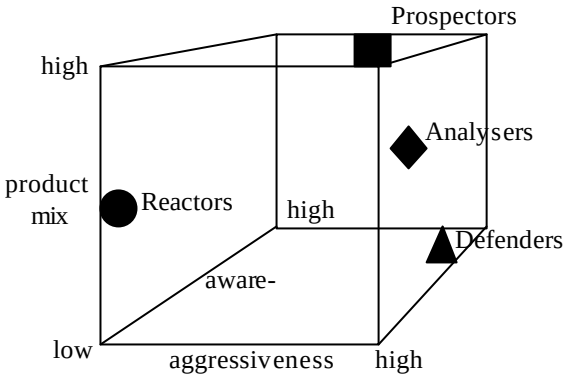

Figure 3. Characteristics of strategic types

The Simulation

1. Initialise product set, consumer set, SME-Agents and simulation count. Select consumer environment scenario.
2. Create random list of SME-Agent and Consumer IDs.
3. Research-Agent compiles list of consumer preferences. If simulation count ? 0, copy current consumer preferences to history list then create a list of all consumer IDs in the current simulation and their current preferences.
4. SME-Agents obtain information on products and can choose to obtain consumer demand information, depending upon rules (Decision: Research).
   a. Take the first SME-Agent ID from the randomised list and send product information request to Products. Update information flow parameter.
   b. Evaluate SME-Agent behaviour.
   If decision = obtain information, request consumer information from Research-Agent, update the cash level and communications flow parameters, else continue. Repeat (b) and (c) for all SME-Agent ID's in the randomised list.
5. SME-Agents buy products, update cash level and stock level (Decision: ProductMix, Buy). Take the first SME-Agent ID from the randomised list and determine SME-Agent behaviour. Update the SME-Agent cash level, stock level and communications flow parameters. Repeat for all SME-Agent IDs in the randomised list.
6. Update randomised list of SME-Agent IDs to include product information.
   a. Take the first SME-Agent ID from the randomised list and add product ID, amount, quality, and price variables to the randomised list.
   b. Update the product ID, longevity, amount and price variables in the randomised list from the matching SME-Agent. Update the quality variable in the randomised list from the Product details.
   c. If more than one product ID, add a row to the randomised list for each product ID. Repeat for all SME-Agent IDs in the randomised list.
7. Consumers obtain information on products for sale and select which products to buy from SME-Agents.
   a. Take the first consumer ID from the randomised list then search the randomised SME-Agent list for consumer preference and SME-Agent product for sale match. When a match is located, SME-Agent details are added to a temporary list of prospective sales for that consumer.
   b. List of prospective sales are sorted according to closest match of price, longevity and quality to consumers preference using the ranking criteria of the consumers conservatism measure.
   c. Sales occur, SME-Agents adjust cash and stock levels. Select first record in temporary list of prospective sales, reduce stock level of SME-Agent, add the value of sales to the cash level and retain the SME-Agent ID, with adjusted stock details, in the randomised list for future sales.
   8. Consumer is replaced/reset depending on chosen consumer environment conditions (i.e. static, turbulent or fashion/trend) and simulation count is incremented.
9. Continue steps 2-8 until end.

DISCUSSION

When implemented, the agent-based model presented in this paper represents SME strategic behaviour and measures associated information flow. Simulations with different populations of SME-Agent strategy typologies and consumer demand scenarios will be used to assess variations in and responses to information flow. The model will be extended to incorporate:

1. emerging and evolving products;
2. other environmental conditions such as perceptions of the broader economic climate; and,
3. additional dimensions of the Miles and Snow typology, such as those in the engineering problem set, focusing on the adoption of technologies.

Finally, the proposed model, and its subsequent extensions, may provide insights into the structure of SME populations and the flows and responses to information within them. An analogy may exist between the flow of information, considered as a resource, and the interpretation of that information in a population of SMEs buying and selling products in a competitive environment, and the structure of ecological communities, commonly represented by food webs [24]

REFERENCES

[1] Australian Bureau of Statistics (2001). *Small Business in Australia (cat. no. 1321.0)*. (electronic). Available at http://www.abs.gov.au [18 July 2003].

[2] McMahon, Richard G. P. (2003) An exploratory study of under- and over-investment amongst manufacturing SMEs from Australia's business longitudinal survey. . *International Small Business Journal* **21** (1):29.

[3] Graham, Peter G. (1999) Small business participation in the global economy. *European Journal of Marketing* **33** (1/2):88

[4] Davidsson, P. and Henrekson, M. (2002) Determinants of the prevalence of start-ups and high-growth firms. *Small Business Economics* 19 (2):81

[5] Kirk, D. (1998) Entrepreneurial context and behaviour in SMEs An investigation of two contrasting manufacturing firms. *International Journal of Entrepreneurial Behaviour & Research* 4 (2):88

[6] Chakravarthy, Bala (1997) "A New Strategy Framework for Coping with Turbulence" *Sloan Management Review* Vol 38 (2) pp. 69-82

[7] Miles, Raymond E. and Snow Charles C. (1978) *Organizational Strategy, Structure and Processes*. McGraw-Hill, New York.

[8] Conant, Jeffrey S; Mokwa, Michael P; Varadarajan, P. Rajan (1990) Strategic Types, Distinctive Marketing Competencies and Organizational Performance: A Multiple Measures-Based Study. *Strategic Management Journal*, 11(5): 365-383.

[9] Smith, Ken G; Guthrie, James P; Chen, Ming-Jer (1989) Strategy, Size and Performance. *Organization Studies*, 10(1): 63-81.

[10] Doty, D Harold; Glick, William H; Huber, George P. (1993) Fit, equifinality, and organizational effectiveness: A test of two configurational theories. *Academy of Management Journal*, 36(6): 1196-1250.

[11] Floyd, Steven W; Wooldridge, Bill (1992) Middle Management Involvement in Strategy and Its Association with Strategic Type: A Research Note. *Strategic Management Journal*, 13(Summer): 153-167.

[12] Chandler, A. D., Jr. (1962) *Strategy and Structure: Chapters in the History of American Industrial Enterprise*, Cambridge, Massachusetts: MIT Press.

[13] Ansoff, H. I. (1965) *Corporate Strategy*, McGraw-Hill.

[14] Mintzberg, H. 1987. 'Five Ps For Strategy'. In Mintzberg, H. and Quinn. J., 1991. *The Strategy Process*. Prentice-Hall, Englewood Cliffs, N.J. 12-19

[15] Porter, M. 1985. *Competitive Advantage*. The Free Press. New York

[16] Miller, D., and P.H. Friesen (1983), Strategy-Making and Environment, The Third Link, *Strategic Management Journal*, 4, 221-235

[17] Zahra, S. and J. Pearce (1990), "Research Evidence on the Miles-Snow Typology", *Journal of Management*, 16, 751-768

[18] McDaniel, Stephen W. and James W. Kolari (1987), "Marketing Strategy Implications of the Miles and Snow Strategic Typology", *Journal of Marketing*, 51, 19-30

[19] Snow, Charles C. and Lawrence G. Hrebiniak (1980), "Strategy, Distinctive Competence, and Organizational Performance", *Administrative Science Quarterly*, 25, 317-335

[20] Hawes, J. and W. Crittenden (1984), "A Taxonomy of Competitive Retailing Strategies", *Strategic Management Journal*, 5, 275-287

[21] Dvir, Dov; Segev, Eli; Shenhar, Aaron (1993) Technology's varying impact on the success of strategic business units within the Miles and Snow typology. *Strategic Management Journal*, 14(2): 155-161.

[22] Holland, J. H. (1995). *Hidden order: How adaptation builds complexity*. New York: Addison-Wesley.

[23] Casti, John L. (1997) *Would-be worlds: How simulation is changing the frontiers of science.* New York: John Wiley & Sons.

[24] Garlaschelli D., Caldarelli G. & Pietronero L. (2003) Universal scaling relations in food webs. *Nature* 423:165-168.