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Using complex adaptive systems and technology to analyse the strength of processes and cultural indicators: a method to improve sustained competitive advantage

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Using complex adaptive systems and technology to analyse the strength of processes and cultural indicators: a method to improve sustained competitive advantage

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Abstract

This paper generalises and strengthens the investigation of capturing intangible data for the benefit of organisations encouraging learning environments and self-organisation practices. It suggests current technological and algorithmic analysis may aid an organisation's quest for sustained competitive advantage through the identification of previously unobservable data including cultural nuances. However, the implementation of such an approach presents challenges of which we summarise in our conclusion.

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1. Introduction

In the 21st Century, organisations are forced to strive for competitive advantage while reacting to the relentless advent of technology, globalisation and diminishing natural resources. Achieving sustained competitive advantage requires more than conserving the milieu we know; it entails a relentless quest for innovation in divergent products and markets that are currently beyond our imagination (O'Reilly and Tushman, 2004).

The achievement of competitive advantage depends greatly on an organisation's capacity to be agile; how quickly and effectively it is able to respond to its environment. Crucial to this capacity is the organisation's human resource. Not only is its knowledge of routines and culture important, but its ability to share this knowledge between current individuals, as well as subsequent generations, allowing an organisation increased buoyancy in the face of change.

This paper presents a nascent idea using technology to gather and monitor knowledge that is currently systematically unobservable, along with the knowledge pertaining to more tangible routines and processes. Using systems based on nature to analyse relationships between employees, managers and other relevant stakeholders, we propose a model that allows comparison between various routines, processes and cultural indicators to identify similarities which we envisage will enable more effective self-organisation within corporations.

In section one; we outline the challenges faced by organisations around the transfer of knowledge. Section two presents a model for a new biologically inspired system that captures tangible and intangible knowledge. In section three we review the implications and outline future work. Finally, section four presents our conclusions.

2. The need for knowledge transfer

In order to achieve agility, a number of factors need to be present within the organisation. Barney (1991) suggests that organisations will achieve agility, and therefore sustained competitive advantage, if it adopts a resource based view (RBV) of its business. RBV includes myriad resources, tangible and intangible, and are not limited to "training, experience, judgment, intelligence, relationships, an insight of individual managers and workers in a firm" (Barney 1991 p101). Of course, processes, routines and coordinating systems are also resources, as are the casual interactions within groups.

When drawing a relationship between RBV and sustained competitive advantage, Barney suggests that not only are firms generating economic value through a unique strategy within their industry at a certain time, but their competitors are incapable of replicating their strategy's success. While Barney's discussion does not stipulate a calendar time frame for competitive advantage to qualify as *sustained* competitive advantage, our suggested model's potential for identifying and measuring unique resources, we believe, can precipitate sustained competitive advantage over calendar time.

While many organisations have frameworks in place to measure the effectiveness of tangible resources, for example, processes and routines, our paper suggests a novel method for identifying and monitoring the intangible unique resources, which by definition are more difficult to replicate and therefore could offer sustained competitive advantage over an even longer calendar timeframe.

Identifying an organisation's resources allows management to cross-pollinate processes and routines, organisation-wide, enabling agile realisation of opportunities (Prahalad and Hamel, 1990). Prahalad and Hamel further suggest that the "collective learning" (p.82) of an organisation represents its core competencies; the coordination of skills along with the amalgamation of myriad technologies, or quite simply, communication. Garud and Nayyar (1994) refer to this communication of internal knowledge as a firm's transformative capacity. Lichtenthaler and Lichtenthaler (2009) adapted this definition to include the *retention* of this knowledge within the organisation. This knowledge must be "actively managed" (p. 1320) for it to flourish

(Lane et al 2006). If organisations do not identify, monitor and communicate processes and routine, organisational competencies become bound and individuals' skills degenerate (Prahalad and Hamel, 1990). As Prahalad and Hamel rightly propose, "unlike physical assets, competencies do not deteriorate as they are applied and shared. They grow." (p82).

Firms possess myriad cultures within the greater organisational culture. Management has the task of identifying and developing these capacities to ensure organisational agility (Robertson 2011). The traditional hierarchical organisation structure does not complement an organisation's need for agility and, therefore, coordination of competencies. Organisations can promote a learning environment that encourages collaboration and risk taking in an effort to achieve innovation quickly.

For organisations to realise a learning environment team members at the coal-face must be empowered to make decisions and adapt quickly to consumer demands. Of course, hierarchical managers indoctrinated with the belief that they hold, and are expected to hold, all knowledge, must overcome this mind-set and allow their team members to not only use their knowledge to execute their own work, but to share their knowledge (Espinosa et al 2007) and contribute to emergent strategies (Burgelman 2002) rather than be controlled solely by management.

An organisation's ability to achieve effective change in dynamic environments, or the organisational *capacity for change (OCC*) (Benn and Bolton, 2011), is vital for organisations to understand. Benn and Bolton suggest a RBV of cultural characteristics that facilitate change readiness, including the preparedness and "employee wellbeing" (p163). As they note, literature around RBV is predominantly focused on evolving and ground-breaking resource building. Interestingly, Bolton (2004) raises the potential for RBV to identify resources that are resilient to change and, therefore, potentially deleterious.

The ability for an organisation to improve its OCC and promote learning at all levels, rather than just at senior management levels for top-down dissemination (Senge 1990; Daft 2009), represents a *complex adaptive system (CAS)* (Holland 1992) that encourages and allows communication and learning throughout the organisation. Holland initially proposed CAS based on the study of naturally occurring systems. These types of self-organising systems are not so easy to model in a simulator, although with *High Performance Computing (HPC)* this is becoming more of a reality.

CAS provides an explanation of patterns that occur within an organisation. It suggests that all parts of the system are intricately related to one another and therefore those pieces of the system that share similarities, or patterns, are attracted and, therefore, present as self-organisation (Olsen and Eoyang 2001)**.** This suggests homogeneous change mechanisms across the across the organisation, if not the wider industry.

Tangible data, or information around routines and processes, are fundamental to an organisation and are generally captured in an organisation's policies and procedures.

With the advent of technology, more of this information is contained on technological systems. Intangible data, likely to be cultural data, is less likely to be captured as part of a formal system. We believe CAS offers an opportunity to model the capturing of tangible data through legacy systems and intangible data through social media applications, or networks, and to use this data to identify patterns within the firm, assisting self-organisation, thereby enabling far greater agility and sustained competitive advantage.

3. A new model

Over the last decade, substantial work has been done analysing the biological world. The principle of the needs of the many out weighing the needs of a few, or the one, is a common adage that few have managed to realise. In the biological world, a collective group is stronger when each individual works for a single, greater, purpose, in effect, self-organising. This phenomenon is studied by academics from many disciplines.

Self-organisation is not solely about ‘pulling together’. Systems can easily have organisation imposed upon them, for example, managers, policies, pre-existing patterns in the environment etcetera. This is common place in businesses, computer networks and many other areas however it is more useful to have a system that is self-organising.

Camazine et al (2004) suggests that self-organisation, in the context of a biological system, is a process in which patterns at the global level of a system emerge solely from the numerous interactions among the lower-level constituents of that system. Furthermore, they affirm that the rules dictating the interactions among the system’s components are carried out using only local information without reference to any global pattern.

As the lower components interact, these patterns emerge without any guiding influence from the global level. The emergent properties cannot be examined by looking at the system’s individual components alone but by considering the interactions between the system’s components.

This is not a new concept. Grout and Houlden (2005) have already proposed that from a networking perspective, the collective good is a potential solution to the problem of routing. Their theory draws on the natural behaviour of ants. Ants work in unison for the good of the colony as they forage for food. If a food supply is found, pheromones are laid down which enables other ants to follow to find the food source; the richer the food source the greater amount of pheromone is applied.

One of the most successful algorithmic techniques based upon ant behaviour, is *Ant Colony Optimisation* (*ACO).* Grout and Houlden (2005) state that ACO is a paradigm for designing metaheuristic algorithms for combinatorial optimisation problems. Metaheuristic algorithms can be best described as:

> *"… algorithms which, in order to escape from local optima, drive some basic heuristic: either constructive heuristic starting from a null solution and adding elements to build a good complete one, or a local search heuristic starting from a complete solution and iteratively modifying some of its elements in order to achieve a better one."*

Ant colonies are complex adaptive systems and, as with many social insect societies, they are a distributed system that, in spite of the simplicity of their individuals, they present a highly structured social organisation (Maniezzo et al 2004). It is this organisation that allows ant colonies to accomplish complicated tasks that in many cases are far beyond the individuals' capabilities.

To focus on ants' systems may seem simplistic however it is an ideal starting point to attempt to model complex adaptive systems. Ants communicate between themselves, or with the environment, by producing chemicals called pheromones. Different species of ants work in different ways. Some species use a trail pheromone which marks pathways, for example from food to nest, which other ants then sense the stronger pheromone trail left by others before them and consequently deposit more pheromone thereby increasing its strength even more. It is the principle of collective trail laying and trial following, based upon chemical path that has inspired ACO.

The ability of ants to work as a cohesive group can be demonstrated with the double bridge experiment. In this experiment Goss et al (1989) establish a long route and a short route for the colony to a food source, ants leave the nest to explore the environment and arrive at a decision point where they have to choose one of the two routes. Because the two branches initially appear identical to the ants, they choose randomly, as the ants reaching the food source will arrive quicker over the shorter route upon their return journey they will follow the route with the 'heavier' pheromone, the shorter one. This trail is then used by successive ants each laying down pheromone.

This simple experiment shows how groups acting together can achieve something for the good of the colony, in this case the shortest route to a food supply. This simplicity has already been applied to other problems, in particular the problem of routing in a computer network. ACO has already proven to be successful in various fields of optimisation.

In particular, Dorigo and Stützle (2004) show how the ACO algorithm can be applied to an *NP*-complete problem like the *Travelling Salesman Problem* (*TSP*). The TSP is a static combinatorial optimisation problem, where the characteristics of the problem are given when the problem is defined and do not change, such as the number of miles between cities. Routing, however, is a dynamic problem where whatever metric we are using for cost could, and probably will, vary. Effective ACO approaches to dynamic routing are beginning to appear (Johnson and Perez, 2005).

It is from the principle of nature, particularly the use of laying down a trail of pheromones, which can be followed, or even just re-used to lead to a goal to help others that our model starts to evolve. Obviously, humans are unable to follow pheromone trails, but we do and can produce digital trails. We often do this when using the Internet and social networking sites, recording what we did and when we did it. Could the exploitation of this type of data allow us to record the intangible? The presence of certain data showing our 'mood' or location when we did something that was successful or not so successful could be extrapolated and then potentially re-used to achieve the same outcome, if desired. The current data held by social networking would not be enough to represent the complex relationships between individuals. However, by using other forms of technology we could capture and analyse some of the intangible resources within an organisation.

The use of technology in self-organising teams may start to help organisations become more agile as changes in business need to come from the bottom up. By using current technology, such as smart phones, tablets and simple devices for measuring brain waves, such as the NeuroSky Mindwave™ to record temperature, light levels, voice patterning and utilising algorithms to monitor different nuances, data can be captured and measured against the outcome of a particular operational routine.

Data, both tangible and intangible, can be gathered at source and then fed in to a data warehouse to be stored. The warehouse also contains each individual operational routine, but not just only what the routine is but it will be broken down to much lower components and a pattern stored. This pattern will be used once data has been gathered as a matching system between similar operational tasks.

The incoming data will be marked as either positive or negative for a particular operational routine, depending upon the outcome of that task; this will then be stored as good (positive) data and will be fed back to the task reinforcing that layer of pheromone.

However, as negative data is gathered from a particular routine, a routine that did not succeed in its outcome or did not reach a pre-established level, then the pheromone is deducted, creating a negative trail.

An algorithm looks at each operational routine and attempts to find one of similar style, using the pattern of that routine that has been stored. If this new routine has strong layers of pheromone attached to it these will be fed in to the routine that has the negative pheromone to try to rectify the problems that it has.

Collecting tangible data is relatively easy when compared with the collection of intangible, but since the relationship has been captured it can be attempted to be reproduced. CAS use this in a very natural way by automatically correcting their environment. Our model to improve self-organisation enables corrections based on proven solutions.

Below are two algorithms, figure 1a and 1b, one showing the data capture routine and the other showing the operational routine comparison.

```
1. Input Capture_data {Capture the stream of incoming data}
2. If Capture_data = + then {Is it positive or negative}
        2.2 Operational_routine_ph = Operational_routine_ph
+ 1{increment the layer of pheromone}
Else
        2.3 Operational_routine_ph = Operational_routine_ph
– 1 {decrement the layer of pheromone}
3. End;
```

Figure 1a - High level data capture algorithm

```
1.  Input Poor_routine, PR← Poor_routine {This is the complete
    operational routine}
2.  Input Good_routine , GR← Good_routine
3.  Input number_of_Ki {Number of key indicators to test}
4.  For x = 1 to max_number_of_routines_to_compare do {Test all
    routines}
    4.1. For i = 1 to number_of_Ki do
         4.1.1. Score ← 0
         4.1.2. Input PRi {PRi is the key indicator i}
                4.1.2.1. If PRi = GRi then {Are the key indicators the same}
                4.1.2.2. Score ← Score + 1
         4.1.3. Output i, Score

    4.2. If Score > number_of_Ki/2 then
         4.2.1. Output GR 'Apply this to ' PR
    4.3. Else if
         4.3.1. Output 'No match'
```

Figure 1b - Operational Routine Comparison

These routines are very high level and are designed to give an idea of how the data will be captured and how an operational routine that is not achieving reasonable results will be compared to one that is achieving better results.

The key indicators used by the algorithm could be a number of datum that can be considered intangible, for instance this could be the amount of daylight, temperature, particular nuances of a person's voice etc.

4. Future Work

While this work is still in its infancy, the usefulness of nature's ideas is well proven. The next steps in this research are establish tests in order to capture data from an array of devices, measuring a wide range of factors, then storing this data and comparing it to the task's outcome. The algorithms themselves need to be refined and tested. From a technical standpoint the data could be stored in an RDBMS (Relational Database Management System) such as Oracle and utilise PLSQL in order to implement the algorithms.

From an organisational perspective, we consider two levels: operational and leadership level.

Operational testing will involve the specification of routines and processes (tangible data). For a series of specified processes or workflows, we will gather an individual's perceived skill level and perceived attitude to the process. This will be matched and compared with actual skill level, through quality assurance processes and actual attitude, using a device such as NeuroSky Mindwave^{TM} . The results of which will be applied to the algorithm (Figure 1b) to ascertain a score. By overlaying the analysis of currently unobservable emotional responses we aim to determine which processes are less effective or generating apathy.

The second branch of testing, leadership, will identify cultural behaviours and pathways, outside of routine and processes, ascertaining which have a positive effect on the organisation and perhaps providing actual measurables around organisational leadership styles and psychological profiles. Again, these tests will include comparison of perceived leadership skills with actual skills and then contrasting these results with perceived attitude with actual attitude using a device such as NeuroSky Mindwave^{TM} . This measurement is somewhat more personal and, as such, we will be incorporating a psychological profiling mechanism in an effort to place more predictive ability behind measuring desired leadership and cultural attributes.

For both levels, we will incorporate standard, well-communicated, processes as well as uncertain and ambiguous communication. We will also be looking for dilution of results as we extrapolate the data to an organisational application.

From a cultural perspective, we plan to use social media to establish an environment for test participants to interact with one another, and an unknown researcher, to collect and score intangible cultural information in a perceived 'safe' environment pertaining to the organisational or leadership testing.

5. Conclusion

In conclusion, for an organisation to achieve competitive advantage, it must be equipped with meaningful data that allows greater understanding of its resources including those which, historically, have been unobservable. For an organisation to achieve sustained competitive advantage, the understanding of patterns and which ones need to be perpetuated or halted may provide longevity to their position in the market. With the burgeoning use of social networking, mobile and other devices, the collection of this ethereal information is becoming more accessible.

As our model suggests, the methods of data collection may be considered invasive, therefore any future studies will involve university ethical approval and volunteers being observed in laboratory conditions rather than real world environments. Our intention is to collaborate with organisational behavioural psychologists to propose a model that includes existing psychological profiles.

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