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An overview of fuzzy Logic

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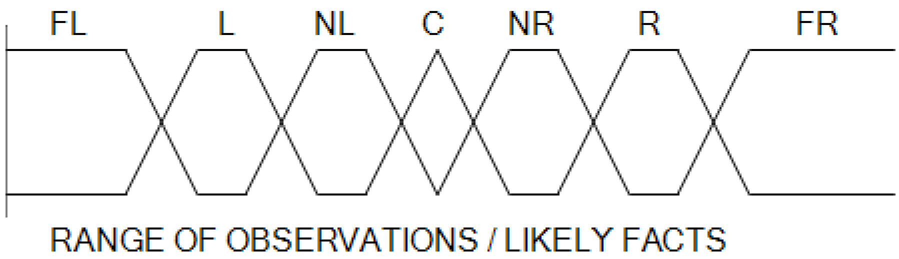
Fuzzy logic, also referred to as Fuzzy set theory was invented by Lotfi Zadeh in 1965 using fuzzy set theory.
In essence, fuzzy logic presents problems in a way similar to how humans think about them or perceive them. That is, we tend to evaluate situations in an imprecise way and yet respond with amazingly effective outcomes – such as crossing a crowded room without coming to a standstill or bumping into numerous people. We achieve this by continually processing inexact measures from the environment and adjusting our actions accordingly. Fuzzy logic gives us the ability to capture this type of human behaviour into Artificial Intelligence (AI) systems. This means that by using language terms and conditional statements, we can, through a system, solve problems without needing EXACT measurements of the input data.

Fuzzy logic recognises that humans are not always precise in the way they allocate facts (observations and information) to groups (categories, classes, collections and so on). Therefore, fuzzy logic represents facts as a matter of degrees rather than the traditional Boolean logic of either true or false. In essence, it regards anything as true and false to some degree.

A simple example suffices: A car can park in either parking lot A or B. Traditional statistics based on certain facts (observations) can tell us with a 95% (or other) confidence interval that the car is parked in say parking lot A. This is the case even if the owner of the car parked a bit skew and left the car 80% in parking lot A and 20% in parking lot B. Fuzzy logic goes beyond the absolutes – that is the car is either 100% in parking lot A or B. It recognises that everything can be true to some degree. That is the car is using up some of A and B's parking space. How accurate the assessment is then dependent on how many possible categories or "fuzzy sets" of data exist against which we can evaluate the problem. The greater the number of fuzzy sets, the more precise and accurate will be the evaluation.

A general approach is to split any value range into seven fuzzy sets. These are: Far Left, Left, Near Left, Centre, Near Right, Right, Far Right. Any kind of meaningful scale or measurement can be linked to these fuzzy sets. For example an organisations ability to deliver quality could be: exceptionally strong, strong, quite strong, neutral, quite weak, weak, and extremely weak.

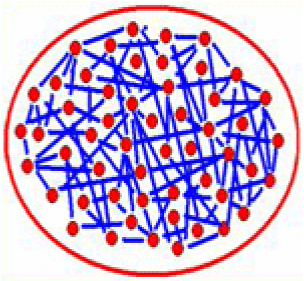
Visually, the fuzzy sets would look something like below (a linear example – lines can be curved for non-linear examples):



Overlapping fuzzy sets ensure smooth transitions between one set to the other. The general rule of thumb is that fuzzy sets should overlap neighbours by around 25%.

Remember with fuzzy logic, we can describe systems linguistically through rule statements such as: "If temperature is Hot and Time of Day is Noon then air conditioning equals very high."

Such language-based descriptions of a system are much easier to produce than complex mathematical models. Each description is in effect an algorithm that represents a part of complex system (such as business). There are many of these algorithms that exist. The great thing about fuzzy logic being used to map and understand these complex systems is that changes in the system have little to no effect upon an algorithm's validity. What's even greater is that we can use more complex techniques that for example use variables that have memory. With these variables in place, we can build rules such as: "If the rear wheels are turning slowly and a short time ago the vehicle speed was high, then reduce rear brake pressure". (A rule used to develop an ABS braking system built on fuzzy logic).



Fuzzy logic provides us with a rich framework and technique for mapping complex systems such as organisations. Yet we must understand that despite the 25% overlap in fuzzy sets, we can break down a situation to smaller and smaller parts (reductionism). This is a classic scientific trick used to get to a detailed understanding of any particular issue. But in the process we often lose sight of the big picture – especially when we try to put the disparate parts back together again (humpty dumpty). This is often the case when trying to understand a business end-to-end. Reducing a very specific business problem to its absolute essential parts independent of the rest of business does little to help us capture and understand the complex impact other business units can have on the problem. Due to this complexity, we have a weak ability to make accurate predictions as to the effectiveness of recommended interventions. However, we have a way forward and it's called complexity theory.
Luckily for us, complexity theory is interested in systems that are essentially too complex to allow for accurate prediction. Through complexity theory, we can build and maintain a holistic and integrated view of business. In other words we can take the fuzzy sets and combine them into a holistic view of the business.

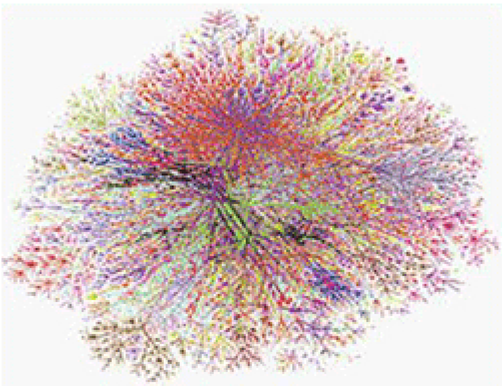
Complexity Theory

Complex systems are ones that usually have a number of individual agents (the red dots) that interact extensively (blue lines) amongst themselves. Agents could be planets, particles (electrons, atoms, gluons, protons etc.), organisations, people, ants, human cells and so on. Due to the complex interactions, we cannot precisely predict what will happen in a complex system, but we can identify and understand patterns. The red-dots can be thought of as complex domains, each with their own rules / norms for interaction. What we know is that each valid complex domain essentially has its own set of rules. For example, Newtonian physics (that is dealing with the very large) has a completely different set of rules / laws than quantum physics (dealing with the very small). Organisations are widely regarded as complex systems.

Key Features of Complex Systems:
Small changes can have big effects in complex systems: This is due to the interactions

that create 'feedback'. A classic example is the broken telephone where you pass a very simple message through a series of people and get the last person to voice the message he or she received. Small variations at the interaction point often result in significant changes to the final message.

Complex systems can have both chaotic and ordered behaviour: Chaos does not imply a lack of structure – there is a clear underlying structure to a complex system in chaotic mode. Chaos merely indicates unpredictability of outcomes. Chaos is not the same as randomness, which implies the lack of underlying structure. Most complex systems move between chaos and order depending on circumstances. This insight is important in that if there is too much order, all agents (e.g. people) in the system act the same way, which results in inflexibility, a lack of innovation and change and a loss of information in relation to a complex system's environment. Likewise, if a system is in chaos mode, we have too much flexibility in the way agents interact and the system dynamics change so rapidly and radically that it becomes impossible to predict or manage. The trick for complex systems such as business is to walk that thin line between chaos and order where there is enough flexibility, innovation and change to ensure an organisation's continued existence.



Complex systems often have fractal structures: A hologram is a fractal – where each part of the image is in fact an exact replica of the whole. A fractal is a shape that repeats itself at different levels within the complex system. Nature's examples of fractals are the human brain, leaves, seashells, our lungs and some human social organisations amongst others. This fractal system means that a few very simple rules and interactions can structure systems that function in very rich and wonderful ways.

Some complex systems have power law distributions: This is the 80:20 rule in operation. 80% of your revenue comes from 20% of your clients or products. In practice it means that a few agents in the system operate at extreme levels, a middle number of agents operate at middle levels and many operate at low levels. Earthquakes follow this rule. There are a few very large earthquakes, a greater number of moderate earthquakes and a large number of small earthquakes. Our lungs and traffic networks also adopt a power law distribution – following a pattern of reducing proportions – trachea into alveoli and highways into a network of smaller roads. This is the case for any complex system having large flows coming into it. In the case of business it could be information and or raw materials into production lines. For our lungs it would be air and for the road system, traffic.
The nature of these power law distributions is often critical for a complex systems effectiveness and continued existence.

Small World Networks are complex systems in operation:

This picture to the right is a small world network made of agents who communicate. In fact, it is a pictorial representation of the Internet. The amazing thing is that no one is in charge, yet the system organises itself and functions to a remarkably effective degree.

As you can see, it is formed around clusters. This is a power law distribution in operation – a few web sites having millions of links, more having thousands of links and millions having a small number of links. For businesses, a small number of people have large social networks whilst most people have small social networks.

Also, the system has a fractal structure. At the most basic level it is computers with links.

Because of the existence of small world networks, researchers globally have noticed the emergence of '**six degrees**'. We are – on average - each separated from each other by six relationships. 75,000 networked individuals across the globe where asked to get a mail message to a specific individual they did not know. The only rule in place was they could only mail the initial email to someone they knew personally. The researchers found the direct route between the original email and the unknown individual receiving the mail involved on average six emails. This is where we derive the six degrees insight. Postal networks, computer networks, terrorist networks, telephone networks as well as drug networks (and we are sure many more) operate according to the six degrees rule. The result is an incredibly effective and efficient network in terms of information transfer, precision capability and effectiveness.

Complex systems have tipping points – especially small word networks: These tipping points relate to the interaction of agents in a complex system. As we take out agents, it does very little to the system as the system finds way to fulfil the function of the missing agents. In other words, the system can still sustain itself. However, as we continue to take agents out, there comes a point where the system cannot find ways to fulfil the function(s) of the missing agents and the system quickly collapses in on itself. This is a negative tipping point.
The reverse is also true – we add agents to a network (for example a new business) to the point where it radically expands. This is a positive tipping point.
Sometimes we want a system to collapse such as where we have an invasion of foreign plant species. At other times, we want systems to radically expand – such as a new business venture. Competition based theories use the concept of tipping points – small advantages can result in market dominance. For example VHS versus BETA in the video solutions and Microsoft versus Apple in desktop software.

Where learning is involved, complex systems become known as Complex Adaptive Systems: these are systems that learn and adapt themselves to their environment. Everything living and organisations fall into this category. From an organisation's perspective, they have the following properties:

- They create a boundary that allows some things in and keeps other things out.
- They get opportunities from outside their immediate environment (raw materials, sales and so on).
- They form themselves into structures that have different levels and hierarchies.
- They have very simple rules in operation that result in very complex behaviour.

- They tend to self organise and take on a life of their own – despite the way we try to manage them.

Complex adaptive systems have many behaviours, but the following are of significance:

Emergence: The behaviour of the system emerges as a result of agents interacting with each other against a few simple rules. The outcomes are neither planned nor controlled, rather they emerge as a result of free agents interacting with each other following a few simple local rules. There is seldom a grand plan.

Co-evolution: Organisations exist within a greater economic and global system. Each of these systems is a part of each other. As the one changes, the others need to change and evolve or face the threat of irrelevance.

Sub optimal, but relative: Organisations don't have to be perfect in order to do well in their environment. They only have to be slightly better than the competition. Once a business is good enough, the best pursue greater effectiveness rather than increased efficiencies.

Requisite Variety: The more variety within the business, the stronger it is. The variety becomes a source of new possibilities that energise change and co-evolution.

Connectivity: The agents in the business must be sufficiently connected to ensure survival of the system. Without these connections, information is not transferred, networks and feedback mechanisms don't form and the system generally does not evolve. In fact, the connectivity enabled between the agents in the system is generally more important than the nature of the agent itself.

Simple Rules: Because of the interaction of the agents and the feedback and emergent behaviour this creates, the rules governing the business can be few and very simple.
Iteration: Information gets fed through the system again and again and each time can gain a new level of significance and or meaning. Therefore small changes to the initial information can quickly become very big changes because of the number of times it is fed through the system.

Self-Organising: Businesses that are complex adaptive systems continually reorganise themselves in relation to their environment. This is because there is no hierarchy of command and control, planning and management. Rather there is a constant self-organisation taking place as the business finds the best fit with its environment.

Close to the tipping point (or on the edge of chaos): Complex adaptive systems by definition operate close to the edge of chaos – otherwise they die because of too much order or they destroy themselves from too much chaos. They marry chaos with order to result in innovation, change and adaptation.

Nested Systems: Most functions and divisions within business operate within other systems – bigger or smaller (for example HR and IT operate in most other functions within the business). Hence, the parts of these systems are parts of different systems, which are in turn parts of other systems. This nestedness results in a great degree of connectivity, even if the nested systems are ignorant of each other.

Complex adaptive systems are all around us. They provide us with a rich framework for designing artificial intelligence solutions in combination with Fuzzy Logic thinking. Given the above discussion, we can develop linguistic based rules that allow us to test and map in a very rich and robust way the existence of some of the following in business:

- The degree of individual autonomy – can agents make their own decisions?
- Presence of risk taking and chaos in the system – is self-organised change taking place?
- Degree of diversity and newness – does the system learn?
- Degree of openness and full participation of agents in the business – does the business exclude or include key agents?
- Extent of effective communication – does the business enable effective networks and change hubs?
- Nature of information flows – bottom up, horizontally, top down – what is the dominant information flows in the business and what is the net effect likely to be on the business?
- Extent to which the business encourages full individual involvement of people – does the business' agents become brand carriers for the business or not?
- Clarity of identity and simplicity of rules – does the business operate in such a way that its agents can deliver results and impact the market?
- Extent to which dominant and recessive traits/stories are used to grow the business – does the leadership team understand this and use it build the business and ensure that leaders emerge in the business?