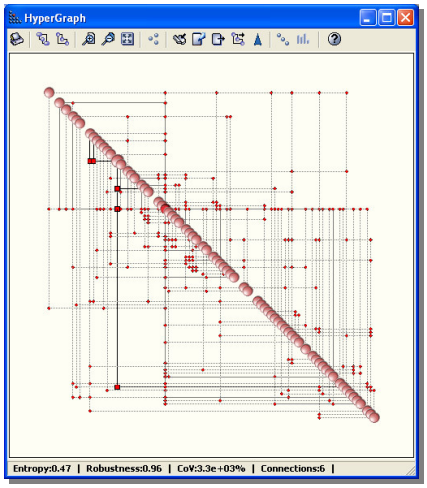
Complexity Management – The Key to Sustainable Development in the 21-st Century

Beyond Optimization – New Paradigms in Decision-Making, Design and Advanced Risk Management

We are witnessing an inexorable increase of complexity in all spheres of social life. Not only is the complexity of man-made products quickly increasing. The economy and the socio-political scenarios are also increasingly more intricate, fragile and difficult to understand. It is becoming evident that under similar circumstances, dominated by chaos and uncertainty, the pursuit of optimality becomes futile. Moreover, optimal solutions are known to be fragile. In the 21-st century we cannot afford optimality. Too much is at stake. Attention must be turned to robustness, comprehensive risk management and sustainability. This is done best via complexity management. When complexity reaches critical levels, systems become fragile and vulnerable when exposed to changing and uncertain environments. Complexity quantification and management, therefore, assume paramount importance. But if you can't measure it, you can't manage it! At Ontonix we have developed innovative methods of measuring and managing complexity. Today it is possible to manage systems and make decisions based on holistic principles that go beyond the unnatural concepts of optimality and optimization. Nature doesn't optimize, so why should we? How can we expect complex systems to function properly if we neglect their salient feature – complexity!

Designing and managing complex systems without taking their inherent complexity into account is like taking a gamble!

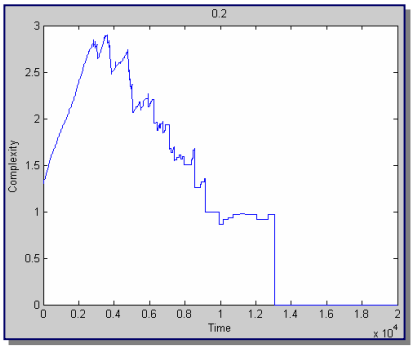


What is Complexity?

A widely accepted definition of complexity doesn't exist. Many of the definitions refer to complexity as "a twilight zone between chaos and order". It is often sustained that in this zone Nature is most prolific and that only this region can sustain life. Others claim that the phenomena of self-emergence are manifestations of complexity. But such definitions are not practical since they don't define anything measureable. At Ontonix we sustain that the fitness of a system is equal to its complexity. The evolution of living organisms, societies or economies constantly tends to states of higher complexity precisely because an increase in functionality and fitness allows these systems to better face the uncertainties of their respective environments, to be more robust, in other words, to survive better. Complexity, in our view, is not a phenomenon on the edge of chaos; it is an attribute of any system, just like energy, or momentum. Therefore, it can be managed.

Why is it Important to Understand and Measure Complexity?

We know that complexity of a given system cannot increase indefinitely. There exist upper limits of complexity which any given system can sustain before degradation or collapse commences. Once we're close to such a threshold, the system becomes fragile and can spontaneously transition to another state – it can run out of hand or even fail. It is evident, therefore, that if we wish to sustain the development of our global society we must know to what limits this development may be safely pushed. We cannot afford to evolve our global society to fragile states. The same may be said of advanced engineering systems, or of large corporations. Consequently, it becomes imperative to study complexity, its evolution, and to understand at what peak levels of complexity societies, markets, corporations or manufacturing processes become fragile. With our technology it is possible, for the first time, to establish these upper complexity thresholds and to help our customers stay away from them. This is precisely complexity management. Moreover, since fragility is synonymous of risk, complexity management becomes the gateway to a new and advanced way of managing risk.



The key in complexity management is to identify the maximum sustainable levels of complexity that a given system main reach. Beyond these values the system becomes fragile and therefore vulnerable.

The Pursuit of Perfection is No Longer the Name of the Game

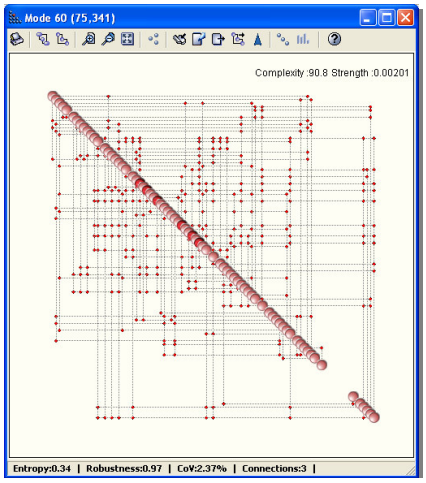
We know that optimal solutions are fragile. Complexity management establishes new rational grounds for better decision-making, design and advanced risk management.

How Can Complexity Management Help to Go Beyond Optimization?

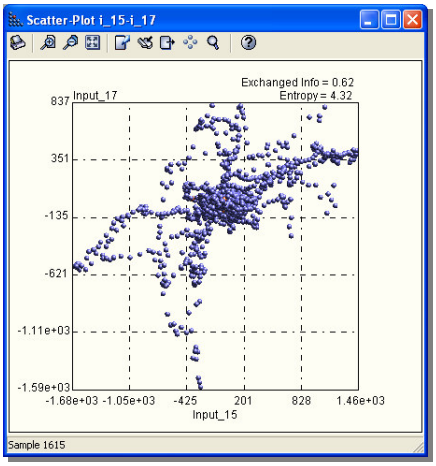
Optimal solutions to complex problems are fragile. This fragility is precisely the price we pay for pushing specialization. *Corruptio optimi pessima*, as the ancient Romans sustained. Today, when designing advanced engineering systems, or when making important business decisions, we can no longer afford to pursue optimal solutions. The pursuit of perfection is no longer the name of the game. It is wiser to opt for robust solutions, seek acceptable compromises, to manage risk. In optimal systems there is little margin for manoeuver. They function well only if all goes according to plan. With complexity management, it is possible to go beyond the inherent fragility of optimal solutions and to address a much more pressing issue, such as sustainability.

How is Complexity Measured?

According to our philosophy, a comprehensive complexity metric should be a function of the following fundamental ingredients: structure, entropy and coarse-graining. Structure describes the way information flows within a given system. This may be represented via maps (graphs) such as those determined by OntoSpace™. Entropy represents uncertainty and the level of organization. Coarse-graining is essentially equivalent to granularity or resolution with which we manipulate data relative to the system. Very often, we can only express fuzzy statements about a system's state (e.g. hot, very hot, extremely hot, etc.) or about given risk levels (very low, low, medium, high or very high). Complexity measures based exclusively on graph structure or entropy tell only part of the story.



The key ingredient of our complexity metric is structure, which is well represented by the so-called modes. These are extracted by OntoSpace™ automatically based on raw data.



Our technology enables to treat highly pathological data. In fact, instead of using conventional statistical techniques, we use our proprietary algorithms to solve the toughest problems.

When Should Complexity Management be Used?

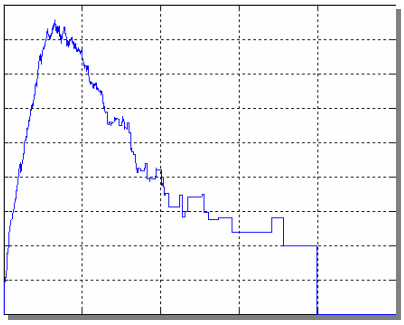
Complexity management can be of paramount importance in any scenario in which high risk, liability or human life is involved, such as:

- Advanced Risk Management (e.g. operational or credit risk)
- Business Process Management (e.g. business diagnosis)
- Financial engineering and economics (e.g. mergers)
- Genomics (e.g. generation of metabolic or genetic networks)
- Social and political studies
- Advanced system monitoring (e.g. stock-market)
- Industrial process analysis
- Defence (e.g. battle management, homeland security)
- Logistics, traffic monitoring and diagnosis
- Conflict anticipation, identification of failing states
- Accident/vulnerability analysis (e.g. insurance, re-insurance)
- Engineering – Complexity-Based CAD, robust design

Complexity Management Opens New Perspectives in Advanced Risk Management

Does an Upper Complexity Limit Exist?

Complexity cannot increase indefinitely. For any given system there exists a critical upper threshold of complexity beyond which it is impossible to evolve. At critical complexity levels, even small increments of entropy will start to erode structure and the system will experience loss of functionality and fitness. Just like in the case of aging. Critically complex systems are fragile. For most systems the critical complexity thresholds are unknown. This is due to the fact that even though the so-called "complex behaviour" has been extensively studied in disparate fields, in very few circumstances has the measurement of the evolution of complexity been actually attempted. Ontonix has the capability of tracking complexity versus time and establishing, for a given system or process, these critical levels of complexity.



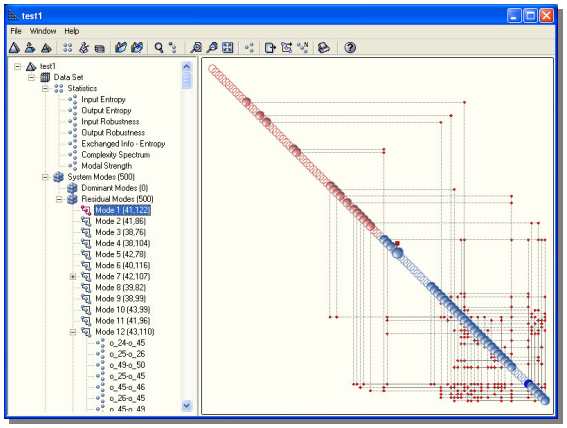
Once peak complexity is reached the system becomes dangerously fragile.

Complexity Management With OntoSpace™

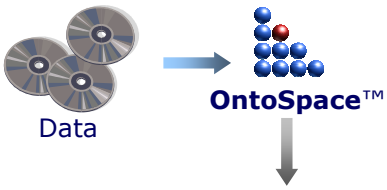
Our complexity management technology may be applied when:

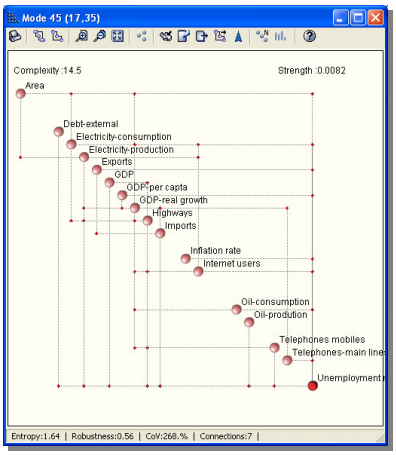
- A computer model of a system is available
- Generic data is available, for example originating from sensors or any other source

Based on a set of data OntoSpace™ identifies a set of distinct patterns of behaviour. These patterns, known as modes, govern the system behaviour and represent the topology of information flow within a system. In each mode, only the significant variables, or actors, are displayed in a clear and intuitive manner via maps. As the user navigates his data, and moves from one state to another, the topology of the maps may change, and new variables may become important, while others may lose relevance. The connections between the active variables represent rules. But what is an organized dynamic set of interrelated rules? It is knowledge. OntoSpace™ is a tool which determines and displays knowledge in a form that is easily understood, managed and shared.



OntoSpace™ is the first software tool for comprehensive complexity quantification and management. It provides the user with unparalleled insight into the behaviour of dynamical systems and their evolution.





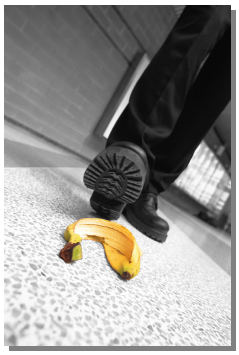
OntoSpace™ automatically determines the modal maps. All that is necessary is a set of raw data. The user need know nothing about the way the variables of his problem interact. The power of OntoSpace™ lies also in its ability to unveil non-intuitive behaviour of systems. In fact, as the complexity of a system increases, the number of possible modes of functioning increases rapidly. One frequent manifestation of high complexity is unexpected mode-switching.

Failure occurs when a system spontaneously jumps to an undesired mode of functioning.

Nature Doesn't Optimize, So Why Should We?

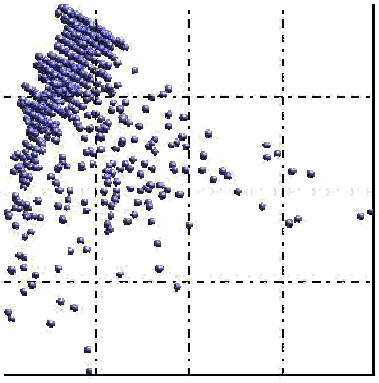
Some Facts About Complexity

- The amount of fitness of a system is proportional to its complexity – higher complexity implies higher fitness
- The amount of functionality of a system is proportional to complexity – more complex system can perform more functions
- Each system can only reach a specific maximum value of complexity
- Close to the upper limit the system is fragile – it is unwise to operate close to this limit
- High complexity = difficulty in management – highly complex systems are able to perform more functions but at a price: they are not easy to manage
- When a system is very complex and becomes difficult to manage, it is necessary to re-structure it, add new structure or to remove excess entropy.
- More components don't necessarily imply more complexity – systems with few components can be more complex than systems with many components.
- When presented with two equivalent options, for example in terms of performance, risk or profit, select the one with the lower complexity – it will be easier to manage.
- Spasms or dramatic changes in dynamical systems are always accompanied by sudden changes in complexity.
- In nature, systems tend toward states of higher complexity, but only until they reach the corresponding maximum. This poses limits to growth and evolution.
- Systems with high complexity can behave in a multitude of ways (modes).
- Systems with high complexity are more difficult to manage and control because of the need to compromise
- A system with a given complexity will be more difficult to manage if it is made to operate in a more uncertain environment.
- High complexity is incompatible with high precision – this is known as L. Zadeh's Principle of Incompatibility. In essence, you can't make precise statements about a highly complex system.
- A fundamental characteristic of highly complex systems: they are robust yet fragile!



Complexity management establishes not only new ways of looking at risk. Risk is exposure to uncertainty! In our highly uncertain world, we must not forget that failure is, unfortunately, an option.

Our Services



Our services are aimed at those who:

- Face complex problems and decisions, involving uncertain environments
- Want to understand risk from a totally new and advanced perspective
- Need to manage risk and liability (warranty, re-calls or law-suits)
- Want to extract knowledge out of data but in a totally new form
- Need to monitor complex systems or plants (e.g. air traffic, power grids)
- Need to monitor and manage intricate time-domain scenarios (battlefield, economy, ecosystem, society, stock-market, etc.)
- Must chose between multiple business options (e.g. mergers or acquisitions)
- Want to identify the limits of sustainability of complex systems
- Have realized that optimal solutions to problems are fragile and robust alternatives are necessary
- Want to reduce process complexity while maintaining performance
- Want to identify critical points and hubs in a process
- Want to determine if a given system can behave in a pathological manner

Complexity X Uncertainty = Fragility

We have established that Complexity x Uncertainty = Fragility. This equation, which is the basis of our business, explains why it is so important to measure, track and understand complexity for any business process. While the uncertainty of a business environment is largely independent of our actions, it is the amount of complexity that can today be actively driven. Clearly, the management of complexity allows us to take a totally new and advanced look at risk management and at robust process design.

OntoSpace™ – A New Look At Knowledge Management

How Can OntoSpace™ Be Used in Decision-making?

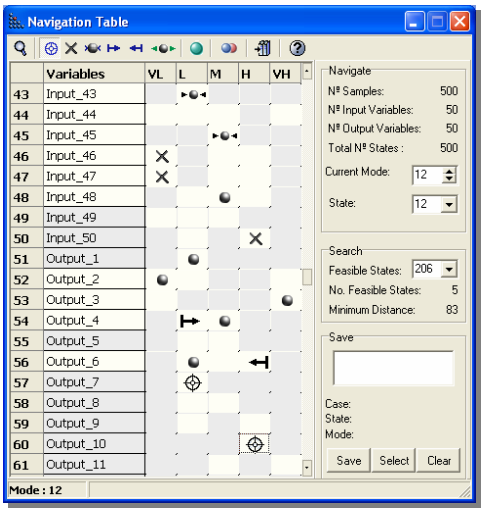
Once data has been processed by OntoSpace™, perform the following simple steps:

- ❑ Using the Interactive Navigation Table: establish constraints and objectives – this can be done for both input and output variables
- ❑ Activate the search for feasible solutions – the process does not involve any form of optimization!
- ❑ OntoSpace™ will return a certain number of potentially different solutions
- ❑ Each solution will have its characteristic complexity
- ❑ Select the solution with the lowest complexity.

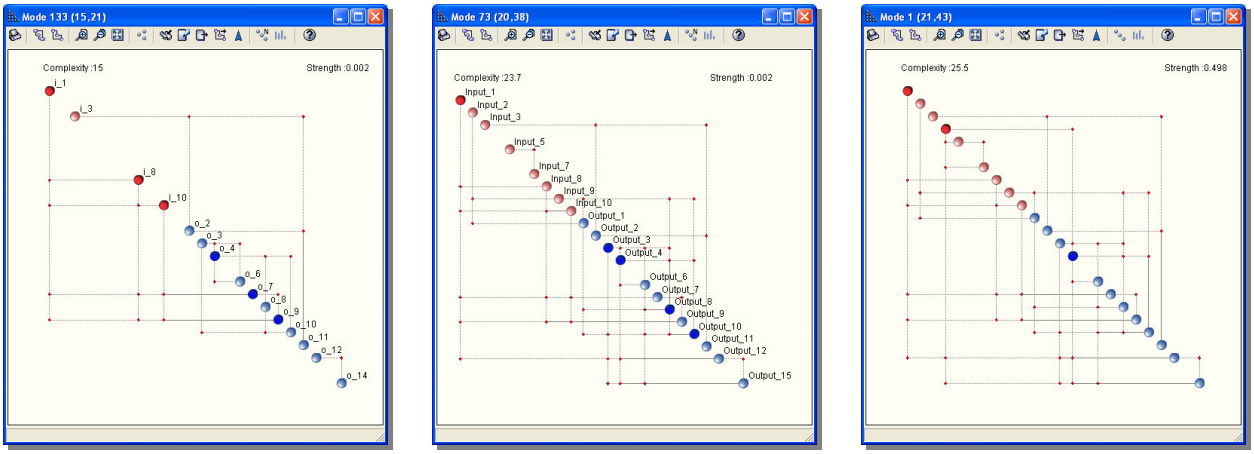
An example of three solutions (modes) is illustrated below: all offer very similar performance and all are acceptable. However, the one on the left is substantially less complex than the other two.

In general, less complex solutions are preferable because of:

- ❑ Easier manufacturability and implementation
- ❑ Easier assembly
- ❑ Easier maintenance
- ❑ Easier management (higher controllability)
- ❑ Lower probability of spontaneous mode-switching



The interactive Navigation Table provides an easy and intuitive environment for exploring data, establishing feasible solutions, performing "What if?" analyses and classifying the various options according to their complexity.



Three equivalent solutions to a particular problem identified via the interactive Navigation Table. All three offer comparable performance but all are characterized by a different degree of complexity. The higher the complexity of a system the more it is difficult to manage and control.

Modes of Functioning or Knowledge Maps?

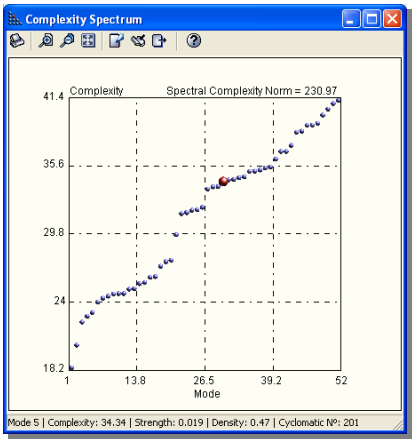
OntoSpace™ extracts modes which represent the possible patterns of behaviour of a given system. Modes are displayed arranging the variables along the diagonal, using different colours for input and output variables. Hubs are indicated in red and blue while significant relationships between the variables are represented by the 'connectors' located off the diagonal. Each such connector establishes, *de facto*, a rule of the type 'if A then B'. The rules are of course fuzzy. Therefore, a mode in practice corresponds to a set of interrelated fuzzy rules in which certain variables may affect one or more variables at the same time. But what is an organized ensemble of sets of interrelated fuzzy rules? Knowledge. OntoSpace™ transforms a multi-dimensional data set into a knowledge base, which may be navigated, interrogated and displayed in a rational and intuitive form.

OntoSpace™- The World's First Tool For Comprehensive Complexity Quantification and Management

Where is the Business Value?

Our technology and services can make a huge difference in business process design and management. We can help our customers answer some fundamental questions such as these:

- Is the business process complex? If so, how complex?
- Is the business process fragile? If so, how fragile?
- If the business process can fail, where are the most likely points of failure?
- Where is the fragility of the business process concentrated?
- In case of failure, what is the most likely way to fail?
- What is the limit of complexity that the business process can sustain without becoming too fragile?
- Can the business process be improved at a reasonable cost? If so, how?
- How does the complexity of the business process affect its manageability?
- Can I perform a high-level global diagnosis of my business process?
- How does knowing the complexity of my business process allow to improve it?
- How can the business process be streamlined (i.e. less fragile)?
- Is the complexity of the process increasing? If so, can we stop it?



OntoSpace™ classifies business options based on complexity and vulnerability, not only on performance.

Our Mission

We all agree with the fact that complexity is probably the most significant characteristic of all aspects of our lives and of our global society. But even though the rapid increase of complexity is a recognized problem, complexity isn't being used in decision-making and management. Our unique OntoSpace™ technology changes this state of affairs. Ontonix has established innovative and comprehensive measures of complexity. It is only when you can measure something you can manage it. The act of measurement constitutes the basis of any serious scientific activity. With our complexity technology our mission becomes to open new horizons in decision-making, design and management of risk. Our goal is to research further this key 21-st century technology and to make it available in a broad range of applications. Our intention is to show our customers that:

- Complexity management establishes a natural, advanced and comprehensive platform for business process management
- Complexity-based design is a better way to achieve robust solutions and decisions.
- Complexity management can help manage risk in an innovative and advanced fashion.
- Sustainable development is impossible without taking a closer look at complexity. There are limits as to how much complexity a given system is capable of sustaining before becoming fragile.
- Innovation is impossible without taking complexity into account.
- In chaotic and uncertain environments, optimization constitutes an expensive alternative as optimal solutions are fragile. Don't forget that optimality and robustness are mutually exclusive.
- Thanks to complexity management, we can move beyond the limitations of optimization.

To find out more, visit us at www.ontonix.com or write to us at info@ontonix.com