Modeling and Applications of Multi-Dimensional Interval Data to Artificial Life, Control Systems, Decision Making, etc.

Tony Nolan
Faculty of Business
University of Technology, Sydney Australia
Email: t.nolan@uts.edu.au

ABSTRACT

By using Interval data, passing it through a matrix and analyzing the results. It is possible to achieve a series of outcomes that will contribute to the cognitive processes of artificial life forms, control systems, intelligent probes and robots, decision-making aids, signposting, models and simulations. This is possible by using a matrix employing finite mathematics environments, fuzzy logic principles, granulated interval mathematics, clustering routines, Euclidean distance measures and multi dimensional inputs. This paper seeks to explore the outcomes of developing Nolan's Matrix, and the contribution of interval mathematics to its operation, and a selection of examples, where the matrix has provided some interesting results.

KEYWORDS: Interval Mathematics, Fuzzy Logic, Modeling.

From the beginning of my life, since I have been able to think and try and understand the world, I have always been asking the question WHY? I have always wanted to know how things worked, what impacted on other things, and to what degree can different causes and effects be modeled. How far into various subsets can you accurately investigate? How can you combine subsets to become a realistic model of reality? Finally, why must I always be limited to three dimensions?

One day, I was called into a colleague's office to help him answer a question concerning a piece of software analysis, and behold I was exposed to a new term of "Dendrogram" - a graphical representation, and the mathematics and matrixes that produced one. My world suddenly opened up and I was about to start on a journey of discovery and the ability to create and investigate multidimensional models.

I realize this is a personal approach to a technical paper on Interval Mathematics. However, rather than explore all the technical uses, I intend to share some concepts and examples of my research. I must firstly apologize to any mathematical purists among you, as I am a trans-disciplinist and hence have created a hybrid system which suits my investigations, and may not use the correct labels nor the correct jargon. My background is not in pure mathematics, so I ask for your patience and hope you enjoy this paper.

The basis of my research revolves around the degree of interactions between both like and unlike units of measure; the relationships both between groups and within groups; and the degree of interrelationships between different stratas and dimensions of both micro and macro environments. Any such modeling exercise, which could be a representation and/or the basis for a control system, needed to be repeatable, rigorous and flexible in the degree of different measurement functions. For this approach the normal arithmetic mathematical scale just wasn't able to cope with the degree of flexibility needed, so I switched to the geometric mathematical scale. In the end I combined both areas of mathematics.

Interval / ratio mathematics proved to be the best possible measurement scale I could have used. For starters, I needed to be able to perform measurements that had a true zero; that had the flexibility to be able to have an infinite degree of measurements between points; and that these points were equal in distance and increments,

thus being equal in quantity independent of the variable measured. Another interesting facet of interval mathematics is its usefulness in modeling and in applications of multi dimensional matrices. Through using distance measures to cluster like and unlike measurement scales, it is possible to display the results by clustering variables on a dendrogram and thereby demonstrate the degree of influence or impact between variables.

Through use of a finite mathematical, fuzzy logical, Euclidean distance matrix using granulated interval clustering, (see my definitions of these terms below) many different possibilities and opportunities open for the development and operations of multi dimensional control systems; artificial life forms; smart probes; decision making; signposting and simulations. The matrix works on the theory of bounded rationality through finite mathematics using fuzzy logic principles.

Finite Mathematics allows the calculations to be bounded within a subjective reality. This is because the universe is too big and complex to model, however certain parts of it can be examined which apply to the problem under investigation. This allows the matrix to be stable and always have a sum of 1. Hence no matter the amount of measurement brought into or removed from the matrix, the sum of interactions will remain constant.

Fuzzy Logic allows the elements of the matrix to be free floating within a finite environment. This gives the process the ability to be clustered while allowing for movement in the areas of importance and impact between the different elements of the matrix. This allows the elements of the matrix to be as flexible as possible, while maintaining the sum of 1.

Granulated interval mathematical techniques emphasises the importance of the smallest movements within and between the different variables of the matrix. This allows the matrix to accommodate different movements within the environment and determine if they have a critical value. Their degree of sensitivity to movement of other variables is critical for the target variable to jump to another level of importance.

Clustering techniques allows the variables to be grouped together which allows for easier analysis and the operation of control systems, or the investigation of the degree of impact on various dimensions which constitute the make up of the matrix.

Euclidean Distance allows the use and comparison of unlike scales or subjective measures to be used in the matrix. This also allows the matrix to have the flexibility to integrate with the other relevant mathematical techniques. By using a geometric mathematical scale, multi dimensional analysis becomes possible.

The Matrix is the pivotal point of the whole process. The matrix becomes the cognition point of the whole process, and sets up the environment/frame work for the process to operate. It is the defining feature, because it allows the integration and analysis of the variables to transcend the limits of the 3d world by allowing variables to be plotted along more than one axis. It allows a warping of space by plotting reference points related to the associated variables in hyperspace.

The outcomes from using a process such as this are many and varied. Following are some examples and outcomes of where the process has been useful.

The ability to snapshot a control situation and to make adjustments in real time, hence maintaining a balanced output is invaluable in control systems. By recording the degree of interactions between sensors, and learnt memories of different matrices for specific situations, the system can judge and react from experience. As

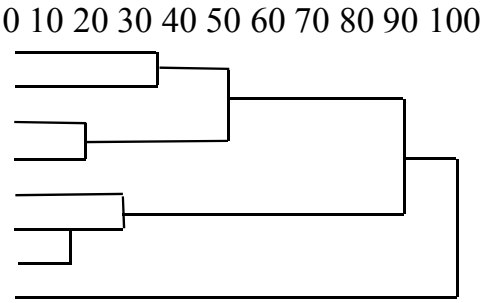
Modeling and Applications of Multi-Dimensional Interval Data to Artificial Life, Control Systems, Decision Making, etc.

long as a desired optimal matrix or situation is known, the computer can self-manage the various inputs in a ‘what if’ scenario, and then output and test the solutions and produce the answer.

Through using the matrix approach, and combining it with knowledge management / knowledge engineering and relational databases it is possible to make smart or intelligent forms, which can be used for simulating decision making. This has applications in exploration probes, and other areas where machine decision making needs a bounded rationality approach. This allows for some autonomous control forms, to be based with a computer system, or within a robotic form.

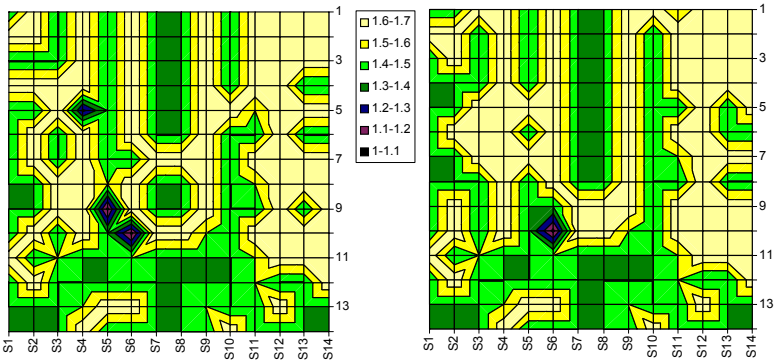
A further form of this which I am developing is called SAHIS, (Simulated Artificial Hybrid Intelligence System) which is an artificial life form, which resides within a computer environment. SAHIS is designed to be a knowledge repository, which stores organizational decisions, and through a multidimensional matrix, helps to create action plans. SAHIS also examines previous decisions; mimics lateral thinking and ‘what if’ scenarios. SAHIS is designed to interact with mechanical and electrical control systems, hence having the ability to become an intelligent control interface.

The matrix allows for snapshots of human decision-making or environmental factors, and allows for the profiling of the interactions between elements as a signature of behaviour. Through using relational databases as well as time series observations, it is possible to signpost situations and develops responses. This also allows for the modeling and simulation of different situations, and allows the computer to understand differences and to suggest possible corrections to the environment to achieve desired outcomes. This process also allows us the use of 'what if' scenarios, and the ability to examine the various outcomes. An example would be mapping a shopping centre, specifically factoring in the human traffic over various seasons. Then when you plan various activities within the centre over time, you can look at the possible outcomes of the changes.



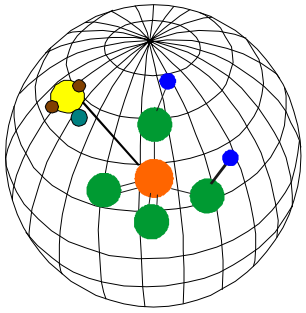
A further ‘what if’ use of the matrix could be by surveying different groups, on the same questions, it is possible to get a dendrogram and a knowledge plane of a person’s or group’s thought patterns. By adjusting the matrix, you can measure the degree of effect a single person or knowledge element can have on the whole matrix. By the capturing of several desired outcomes matrices, it is possible to capture an undesired matrix, and get the computer to plot several interventions to cause a change towards the desired outcome. An example is when you have different work teams within the same workplace. By getting a matrix from the best team, and then one from a lesser team, it is possible for the computer to suggest various aspects that may cause a change for the better in the second team, in areas such as training, conditions or work practices.

By using contour maps of the matrix, and by using a selection of colours, it is possible to make contour and topographical maps of the matrix plane. This allows a visual comparison of the degrees of variance between the intersection of two or more matrix planes. By reordering the variables by ranking on either the row or column totals, its possible to



examine nearest neighbour or furthest neighbour scenarios. Following is an example of the difference that can be attributed to a single person changing their mind, on a few issues within the matrix.

A matrix can also be used to construct a Fuzzy Knowledge Sphere which is a three dimensional form of the contour maps discussed above. The fuzzy sphere is like a model of the solar system, where you have the sun, planets and moons. Where the model differs is that all points in the model are static. The distances and the positions of the objects are set in a fixed location, where its coordinates are set by a classification system. The system works similarly to a fractal, where each sub-grouping represents the parent in the same classification system, but it varies from a fractal, in that the entire subset make look very different to its parent. Hence it is possible to map the different points in real space and examine the different clusters and degree of effect on a decision. It is also possible to map these positions over time, and to examine the differences of object over time, or to examine the disturbance caused by an addition or withdrawal of another variable.



Various areas where the matrix or at least the technique can be used are still being explored. Current explorations include modelling various environments, investigation of weather patterns, the greenhouse effect and finally in artificial life forms/quasi humans and in autonomous control robots. It has already proved its value in some areas, and I hope to develop it further in the following years. I would be happy to explore any issues that people may have with the contents of this paper.

Further published accounts of the matrix in use, include:

Nolan, A. *Getting underneath the decision making process*, in Modsim 95 proceedings, Modelling and Simulation Association, Newcastle, 1995 or:

Sheather, G. & Nolan, T. *Solving reshelving backlogs in a university library: a case study an interactive problem-solving technique with a TQM application.* Australian library journal. Feb. 1995.