NEUTROSOPHIC COGNITIVE MAPS
AND NEUTROSOPHIC RELATIONAL MAPS

Properties and Applications

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Introduction.

In a world of chaotic alignments, traditional logic with its strict boundaries of truth and falsity has not imbued itself with the capability of reflecting the reality.

Despite various attempts to reorient logic, there has remained an essential need for an alternative system that could infuse into itself a representation of the real world.

Out of this need arose the system of Neutrosophy, and its connected logic, Neutrosophic Logic.

Neutrosophy is a new branch of philosophy that studies the origin, nature and scope of neutralities, as well as their interactions with different ideational spectra.

It proposes new philosophical theses, principles, laws, methods, formulas and movements; it reveals that the world is full of indeterminacy; it interprets the uninterpretable; regards, from many different angles, old concepts, systems and proves that an idea which is true in a given referential system, may be false in another, and vice versa.

Introduction - cont.

The main principle of neutrosophy is:

Between an idea <A> and its opposite <Anti-A>,
there is a continuum-power spectrum of Neutralities.

This philosophy forms the basis of Neutrosophic logic.

Neutrosophic logic grew as an alternative to the existing logics and it represents a mathematical model of uncertainty, vagueness, ambiguity, imprecision, undefined, unknown, incompleteness, inconsistency, redundancy, contradiction.

It can be defined as a logic in which each proposition is estimated to have the percentage of truth in a subset *T*, the percentage of indeterminacy in a subset *I*, and the percentage of falsity in a subset *F*, is called Neutrosophic Logic.

Introduction - cont.

We use a subset of truth (or indeterminacy, or falsity), instead of using a number, because in many cases, we are not able to exactly determine the percentages of truth and of falsity but to approximate them: for example a proposition is between 30-40% true.

The subsets are not necessarily intervals, but any sets (discrete, continuous, open or closed or half-open/ half-closed interval, intersections or unions of the previous sets, etc.) in accordance with the given proposition.

A subset may have one element only in special cases of this logic.

It is imperative to mention here that the Neutrosophic logic is a further generalization of the theory of Fuzzy Logic.

In this presentation, we study the concepts of Fuzzy Cognitive Maps (FCMs) and their Neutrosophic analogue, the Neutrosophic Cognitive Maps (NCMs).

Introduction - cont.

Fuzzy Cognitive Maps are fuzzy structures that strongly resemble neural networks, and they have powerful and far-reaching consequences as a mathematical tool for modeling complex systems.

Prof. Bart Kosko, the guru of fuzzy logic, introduced the Fuzzy Cognitive Maps in the year 1986.

Kosko, B. Fuzzy Cognitive Maps, Int. J. of Man-Machine Studies, 24 (1986) 65-75.

It was a fuzzy extension of the cognitive map pioneered in 1976 by political scientist Robert Axelrod [5], who used it to represent knowledge as an interconnected, directed, bilevel-logic graph.

Axelord, R. (ed.) Structure of Decision: The Cognitive Maps of Political Elites, Princeton Univ. Press, New Jersey, 1976.

Till today there are over a hundred research papers which deal with FCMs, and the tool has been used to study real-world situations as varied as stock-investment analysis to supervisory system control, and child labor to community mobilization against the AIDS epidemic.

Introduction - cont.

The special feature of NCMs is their ability to handle indeterminacy in relations between two concepts, which is denoted by *I*.

This new structure — the NCM is capable of giving results with greater sensitivity than the FCM.

It also allows a larger liberty of intuition by allowing an expert to express not just the positive, negative and absence of impacts but also the indeterminacy of impacts.

Practically speaking, we must be aware that even in our day-to-day lives, the indeterminacy and unpredictability of life, affect us almost as much as the determined factors.

It is a major handicap in mathematical modeling that we are only able to give weightages for known concepts; and most of the time we exhibit an unconcern for indeterminate relationships between concepts, thereby presenting onto ourselves a skewed view.

Introduction - cont.

Some of the varied applications of FCMs and NCMs (and alternately FRMs and NRMs) include:

- modeling of supervisory systems;
- design of hybrid models for complex systems;
- mobile robots and in intimate technology such as office plants;
- analysis of business performance assessment;
- formalism debate and legal rules;
- creating metabolic and regulatory network models;
- traffic and transportation problems;
- medical diagnostics;
- simulation of strategic planning process in intelligent systems;
- specific language impairment;
- web-mining inference application;

Introduction - cont.

Applications of FCMs and NCMs (and alternately FRMs and NRMs) include - cont:

- child labor problem;
- industrial relations: between employer and employee, maximizing production and profit;
- decision support in intelligent intrusion detection system;
- hyper-knowledge representation in strategy formation;
- female infanticide;
- depression in terminally ill patients;
- community mobilization;
- women empowerment relative to the AIDS epidemic,

etc.

Definition of Fuzzy Cognitive Maps

An FCM is a directed graph with concepts like policies, events etc. as nodes and causalities as edges. It represents causal relationship between concepts.

Example.

In Tamil Nadu (a southern state in India) in the last decade several new engineering colleges have been approved and started. The resultant increase in the production of engineering graduates in these years is disproportionate with the need of engineering graduates. This has resulted in thousands of unemployed and underemployed graduate engineers. Using an expert's opinion we study the effect of such unemployed people on the society. An expert spells out the five major concepts relating to the unemployed graduated engineers as

E1 – Frustration

E2 – Unemployment

E3 – Increase of educated criminals

E4 – Under employment

E5 – Taking up drugs etc.

Definition of Fuzzy Cognitive Maps - cont.

The directed graph where E1, …, E5 are taken as the nodes and causalities as edges as given by an expert is given in the following *Figure*:

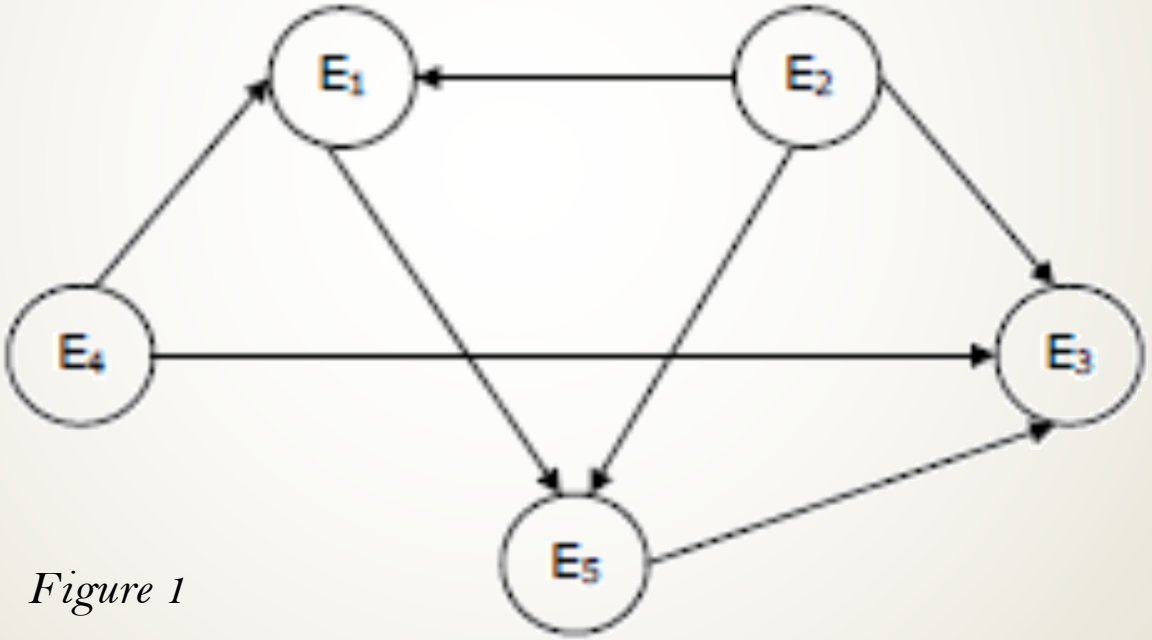


Figure 1

Definition of Fuzzy Cognitive Maps - cont.

According to this expert, increase in unemployment increases frustration.

Increase in unemployment, increases the educated criminals.

Frustration increases the graduates to take up to evils like drugs etc.

Unemployment also leads to the increase in number of persons who take up to drugs, drinks etc. to forget their worries and unoccupied time.

Under-employment forces then to do criminal acts like theft (leading to murder) for want of more money and so on.

Thus one cannot actually get data for this but can use the expert's opinion for this unsupervised data to obtain some idea about the real plight of the situation.

This is just an illustration to show how FCM is described by a directed graph.

Definition of Fuzzy Cognitive Maps - cont.

FCMs have several advantages as well as some disadvantages.

The main advantage of this method it is simple. It functions on expert's opinion. When the data happens to be an unsupervised one the FCM comes handy. This is the only known fuzzy technique that gives the hidden pattern of the situation. As we have a very well known theory, which states that the strength of the data depends on, the number of experts' opinion we can use combined FCMs with several experts' opinions.

At the same time the disadvantage of the combined FCM is when the weightages are 1 and –1 for the same C_i C_j, we have the sum adding to zero thus at all times the connection matrices $E_1, \ldots, E_k$ may not be conformable for addition.

Combined conflicting opinions tend to cancel out and assisted by the strong law of large numbers, a consensus emerges as the sample opinion approximates the underlying population opinion.

This problem will be easily overcome if the FCM entries are only 0 and 1.

Fuzzy Cognitive Maps – Properties and Models

Fuzzy cognitive maps (FCMs) are more applicable when the data in the first place is an unsupervised one.

The FCMs work on the opinion of experts.

FCMs model the world as a collection of classes and causal relations between classes.

FCMs are fuzzy signed directed graphs with feedback. The directed edge e_{ij} from causal concept C_i to concept C_j measures how much C_i causes C_j.

The time varying concept function $C_i(t)$ measures the non negative occurrence of some fuzzy event, perhaps the strength of a political sentiment, historical trend or military objective.

FCMs are used to model several types of problems varying from gastric-appetite behavior, popular political developments etc.

FCMs are also used to model in robotics like plant control.

Fuzzy Cognitive Maps – Properties and Models - cont.

We illustrate by the following *Figure*, which gives a simple FCM of a Socio-economic model. A Socio-economic model is constructed with Population, Crime, Economic condition, Poverty and Unemployment as nodes or concept.

Here the simple trivalent directed graph is given by the following *Figure*, which is the experts opinion.

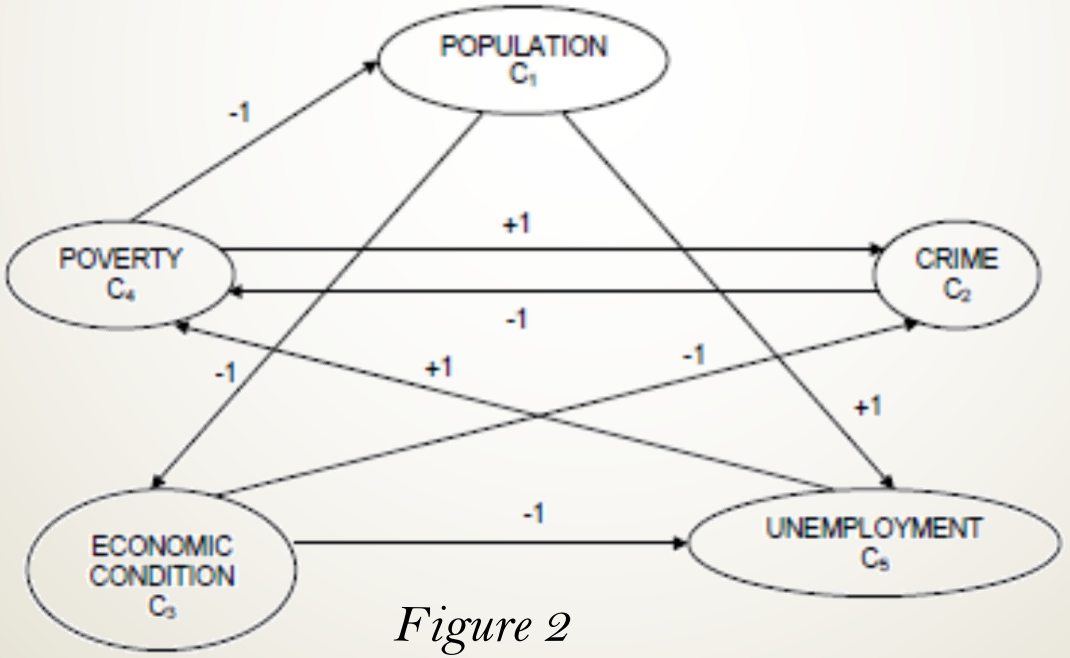


Figure 2

Fuzzy Cognitive Maps – Properties and Models - cont.

Causal feedback loops abound in FCMs in thick tangles. Feedback precludes the graph-search techniques used in artificial-intelligence expert systems.

FCMs feedback allows experts to freely draw causal pictures of their problems and allows causal adaptation laws, infer causal links from simple data. FCM feedback forces us to abandon graph search, forward and especially backward chaining. Instead we view the FCM as a dynamical system and take its equilibrium behavior as a forward-evolved inference. Synchronous FCMs behave as Temporal Associative Memories (TAM).

We can always, in case of a model, add two or more FCMs to produce a new FCM. The strong law of large numbers ensures in some sense that knowledge reliability increases with expert sample size.

We reason with FCMs. We pass state vectors C repeatedly through the FCM connection matrix E, thresholding or non-linearly transforming the result after each pass. Independent of the FCMs size, it quickly settles down to a temporal associative memory limit cycle or fixed point which is the hidden pattern of the system for that state vector C. The limit cycle or fixed-point inference summarizes the joint effects of all the interacting fuzzy knowledge.

Fuzzy Cognitive Maps – Properties and Models - cont.

Example.

Consider the 5×5 causal connection matrix E that represents the socio economic model using FCM given in figure in *Figure 2* above.

$$E = \begin{bmatrix} 0 & 0 & -1 & 0 & 1 \\ 0 & 0 & 0 & -1 & 0 \\ 0 & -1 & 0 & 0 & -1 \\ -1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix}$$

Concept nodes can represent processes, events, values or policies. Consider the first node $C1 = 1$. We hold or clamp $C1$ on the temporal associative memories recall process. Threshold signal functions synchronously update each concept after each pass, through the connection matrix E. We start with the population $C1 = (1\ 0\ 0\ 0\ 0)$.

Fuzzy Cognitive Maps – Properties and Models - cont.

The arrow indicates the threshold operation,

$$
\begin{array}{lcccccc}
C_1E & = & (0\,0\,-1\,0\,1) & \rightarrow & (1\,0\,0\,0\,1) & = & C_2 \\
C_2E & = & (0\,0\,-1\,1\,1) & \rightarrow & (1\,0\,0\,1\,1) & = & C_3 \\
C_3E & = & (-1\,1\,-1\,1\,1) & \rightarrow & (1\,1\,0\,1\,1) & = & C_4 \\
C_4E & = & (-1\,1\,-1\,0\,1) & \rightarrow & (1\,1\,0\,0\,1) & = & C_5 \\
C_5E & = & (0\,0\,-1\,0\,1) & \rightarrow & (1\,0\,0\,0\,1) & = & C_6 = C_2.
\end{array}
$$

So the increase in population results in the unemployment problem, which is a limit cycle.

This example illustrates the strengths and weaknesses of FCM analysis. FCM allows experts to represent factual and evaluative concepts in an interactive framework.

Experts can quickly draw FCM pictures or respond to questionnaires.

Experts can consent or dissent to the local causal structure and perhaps the global equilibrium.

Fuzzy Cognitive Maps – Properties and Models - cont.

The FCM knowledge representation and inference-ing structure reduces to simple vector matrix operations, favors integrated circuit implementation and allows extension to neural statistical or dynamical systems techniques.

Yet an FCM equally encodes the experts' knowledge or ignorance, wisdom or prejudice.

Worse, different experts differ in how they assign causal strengths to edges and in which concepts they deem causally relevant.

The FCM seems merely to encode its designers' biases and may not even encode them accurately.

FCM combination provides a partial solution to this problem. We can additively superimpose each experts FCM in associative memory fashion, even though the FCM connection matrices $E_1, \ldots, E_k$ may not be conformable for addition.

Combined conflicting opinions tend to cancel out and assisted the strong law of large numbers a consensus emerges as the sample opinion approximates the underlying population opinion.

FCM combination allows knowledge researchers to construct FCMs with iterative interviews or questionnaire mailings.

Applications of Fuzzy Cognitive Maps.

FCM is used in modeling of supervisory systems, in the design of hybrid models for complex systems, in the International Advanced Robotics Program, in business performance assessment, in analyzing legal problems, etc. FCM model has also been applied in case of transportation problems like passengers preference, peak-hour problem, stock investment analysis, etc.

APPLICATION 1: Modeling Supervisory systems using FCM

In the application of FCM, Stylios and Groumpos have given a new methodology, an FCM for modeling the supervisor of a complex control system.

Stylios, C.D., and P.P. Groumpos. The Challenge of Modeling Supervisory Systems using Fuzzy Cognitive Maps, J. of Intelligent Manufacturing, 9 (1998) 339-345.

An FCM has been implemented in a simple process control problem that makes apparent the qualities and characteristic of the method. It has been observed how simply an FCM describes a system's behaviour and its flexibility in any change of system.

Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 1: Modeling Supervisory systems using FCM – cont.

A more integrated approach i.e. a two-level structure where the FCM is the upper level, is used for more sophisticated supervisory control of manufacturing systems which is given in *Figure* below.

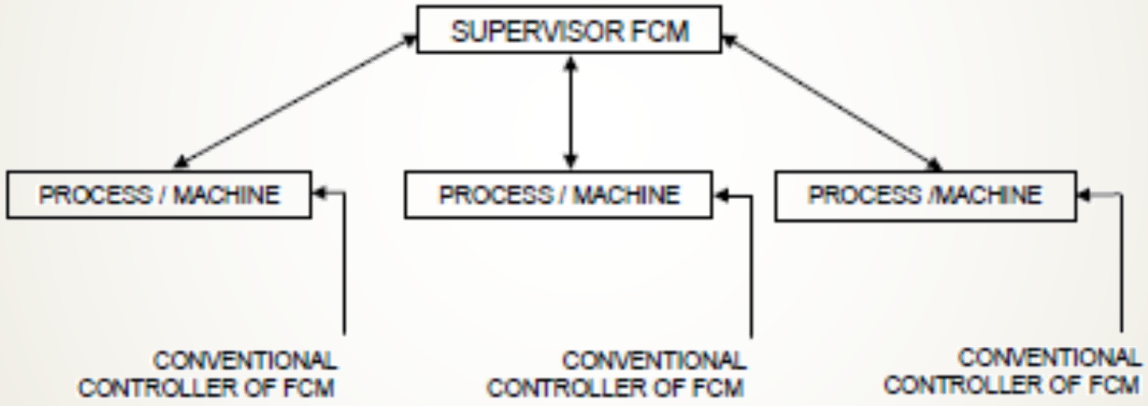


Figure 3

The most important use of an FCM is for supervisory control of a conventional control element, thus complementing rather than replacing a conventional controller.

Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 1: Modeling Supervisory systems using FCM – cont.

Thus the FCM may replicate some of the knowledge and skills of the control engineer and it is built using a combination of knowledge representation techniques as causal models, production rules and object hierarchies and it is used to perform more demanding procedures such as failure detection, decision making and planning (tasks usually performed by a human supervisor of the controlled process).

In the upper level a supervisory FCM will include advanced features such as fault diagnosis, effects and cause analysis, prediction capabilities, decision analysis and strategic planning.

The FCM will consist of concepts that stand for the irregular operation of some elements of the system, for failure mode variables for failure effects variables, for failure cause variable, severity of effects, design variables. Thus Stylios and Groumpos have used the construction of a map mainly based on the operators heuristic knowledge about alarms, faults, what are their causes, and when they happen.

Stylios, C.D., and P.P. Groumpos. The Challenge of Modeling Supervisory Systems using Fuzzy Cognitive Maps, J. of Intelligent Manufacturing, 9 (1998) 339-345.

Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 2: FCM applied in the Design of Hybrid Models for Complex Systems.

A Fuzzy Cognitive Map is used to aggregate separate models and to fit more precisely the plant behaviour at different operational conditions. One of the important advantages of fuzzy logic methodologies such as FCMs is that they are applicable to task oriented problems.

Hadjiski et al. used FCMs to aggregate the set of different modeling technologies. FCMs best utilize existing experience in the operation of the system and are capable in modeling the behaviour of complex systems.

FCMs seem to be a useful method in complex system modeling and control which will help the designer of a system in decision analysis. They are an appealing tool in the description of the modeling techniques, which teamed up with other methods will lead to be more sophisticated model and control design systems.

Hadjiski, M. B., Christova, N.G., and Groumpos, P.P. Design of hybrid models for complex systems. http://www.erudit.de/erudit/events/esit99/12773_p.pdf

Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 2: FCM applied in the Design of Hybrid Models for Complex Systems - cont.

FCMs are used to aggregate the separate models and to perform a kind of maintenance of the system by integrating alternative modeling techniques.

An augmented FCM can accomplish identification of the process models and cope with limited uncertainty situations.

It may comprise different models, identification and estimation algorithms.

Using FCMs, which best utilize existing experience in the operation of the system and are capable in modeling the behaviour of the complex systems.

FCMs seem to be a useful method in complex system modeling and control which will help the designer of a system in decision analysis.

FCMs appear to be an appealing tool in the description of the modeling techniques, which teamed up with other method will lead to the more sophisticated model and control design systems.

Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 3: Use of FCMs in Robotics: Mobile Robots performing Cutting Operations and Intimate Technologies like Office Plant.

Bohlen M. and Mateas M. make use of FCMs in their research on Office Plant.

Office Plant #1 (OP#1) is an exploration of a technological artifact, adapted to the office ecology, which fills the same social and emotional niche as an office plant.

OP#1 monitors the ambient sound and light level, and, employing text classification techniques, also monitors its owner's email activity. Its robotic body, reminiscent of a plant in form, responds in slow, rhythmic movements to comment on the monitored activity. In addition, it makes its presence and present knowledge known through low, quiet, ambient sound.

OP# is a new instantiation of our notion of intimate technology, that is, technologies which address human needs and desires as opposed to technologies which meet exclusively functional task specifications. OP#1 lives in a technological niche and interacts with users through their use of electronic mail. It acts as a companion and commentator on these activities.

Bohlen, M. and M. Mateas. Office Plant #1.

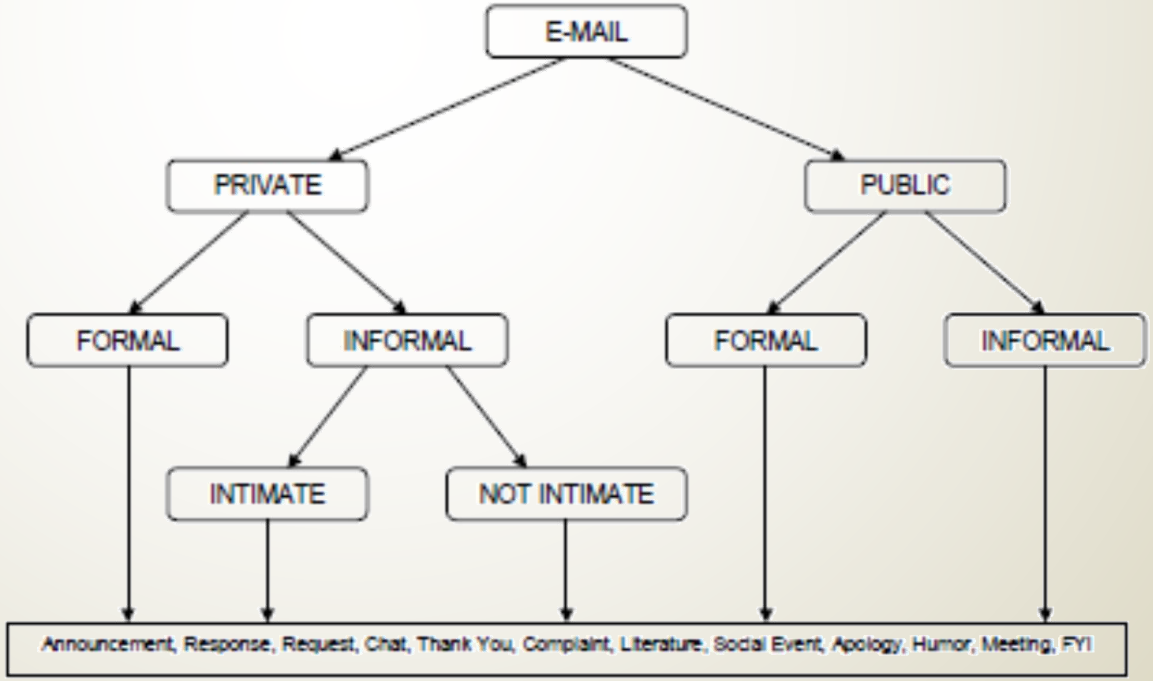
http://www.acsu.buffalo.edu/~mrbohlen/pdf/leonardo.pdf

Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 3: Use of FCMs in Robotics: Mobile Robots performing Cutting Operations and Intimate Technologies like Office Plant - cont.

Here we describe the major artistic and technical concepts that underlie the design of OP#1. These concepts are: E-mail Space, Text Classification, Plant Behavior Architecture, and Sculptural Presence. In our practice we simultaneously explore both spaces; artistic and technical constraints and opportunities mutually inform each other.

Figure 4



Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 3: Use of FCMs in Robotics: Mobile Robots performing Cutting Operations and Intimate Technologies like Office Plant - cont.

Figure previous slide depicts the category tree employed by OP#1.

An email message is either private (addressed to a single person) or public (multiple address). The tone can be either formal or informal. Private, informal email can be intimate, that is, email addressed to close friends.

After passing through this initial category tree, every message can be assigned one or more of the categories in the box at the bottom of the figure.

In this categorization scheme, every message is assigned a set of labels.

For example, a message may be a public, informal announcement, or a private, informal, humorous request.

The state of the plant is dynamically modeled with a Fuzzy Cognitive Map (FCM).

Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 3: Use of FCMs in Robotics: Mobile Robots performing Cutting Operations and Intimate Technologies like Office Plant - cont.

In a FCM, nodes representing actions and variables (states of the world) are connected in a network structure reminiscent of a neural network.

FCMs are fuzzy signed digraphs with feedback. Nodes stand for fuzzy sets or events that occur to some degree.

At any point in time, the total state of the system is defined by the vector of node values.

In this implementation, the nodes represent actions.

The action associated with the action node with the highest value is executed at each point in time.

The values of nodes change over time as each nodes exerts positive and negative influence on the nodes it is connected to.

The FCM approach is attractive because it can resolve contradictory inputs and maintains sufficient state to exhibit incremental effects.

Next slide *Figure* shows the FCM for OP#1.

Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 3: Use of FCMs in Robotics: Mobile Robots performing Cutting Operations and Intimate Technologies like Office Plant - cont.

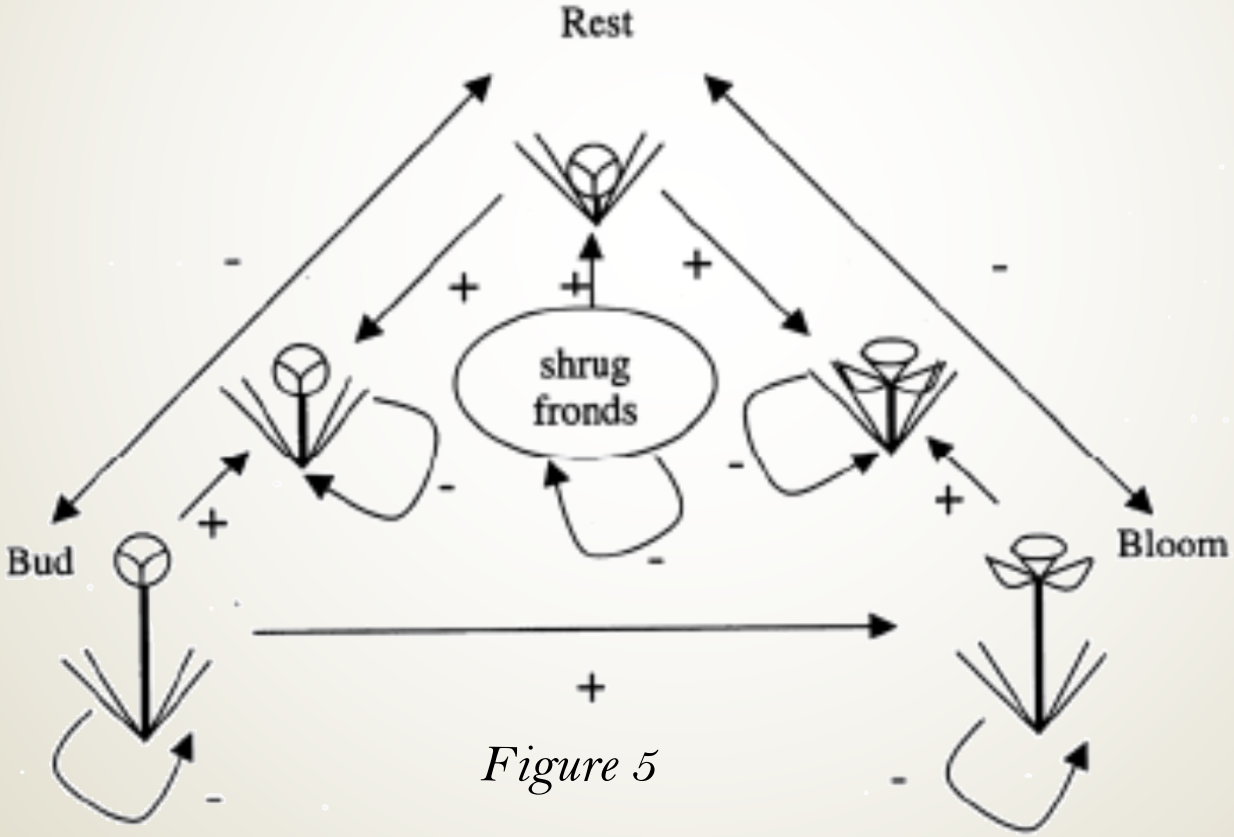


Figure 5

Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 3: Use of FCMs in Robotics: Mobile Robots performing Cutting Operations and Intimate Technologies like Office Plant - cont.

Office Plant #1 is a desktop sculpture, an office machine that serves as a companion.

In an environment of button pushing activity, OP#1, like a good piece of sculpture, is always on. OP#1 creates its own kind of variable presence in a user's email space, taking on various attitudes and falling into decided silence.

In its reactions it is a commentator on the events it analyzes. It goes beyond mirroring these events and delivers reactions as if it understood the significance of the exchange.

But effectively, OP#1 is mostly inactive. It has a well defined sense of doing nothing, yet. It is simply there and in that sense a tradition piece of sculpture. Its physicality is as important as its text classifying capabilities.

OP#1's activity cycle is given by a defined period of 24 hours.

During the active office hours it is receptive to user presence.

After hours it uncouples itself from the daily trivia as it moves into a contemplative space for regeneration.

Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 3: Use of FCMs in Robotics: Mobile Robots performing Cutting Operations and Intimate Technologies like Office Plant - cont.

Figure above shows the Fuzzy Cognitive Map relating physical plant states.

The three primary physical postures of the plant are rest (protect), bud and bloom.

In rest, the bulb is closed and fully lowered. The fronds occasionally move. In bud, the bulb is closed and fully extended. In bloom, the bulb is open and fully extended.

When the node associated with a posture has the most activation energy, the plant performs the action of moving to this posture from its current posture frond is the action of tweaking one or more of the fronds.

Activation energy from shrug flows towards rest. If the plant is shrugging too much, it moves into a protective posture.

Activation energy from bud flows towards bloom; budding makes blooming more likely. Rest and bud, and rest and bloom, are mutually inhibitory. Rest and bud both spread their energy to an intermediate posture, and rest and bloom spread their energy to a second intermediate posture.

Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 3: Use of FCMs in Robotics: Mobile Robots performing Cutting Operations and Intimate Technologies like Office Plant - cont.

The combination of the mutual inhibition plus the intermediate posture will cause these pairs of states to compromise towards the intermediate posture will cause these pairs of states to compromise towards the intermediate posture.

Finally, the self inhibitory links tend to cause values in the system to decay; in the absence of input, the plant will not stay in a posture forever.

When all of the nodes are zero, the plant will move towards the rest posture.

As email is classified, energy is added to nodes, thus initiating the process of competition and cooperation between the nodes.

Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 4: Use of FCM in medical diagnostics.

FCMs have been very handy in medical diagnostics.

Here we discuss an article by Vysoky.

Vysoký, P. Fuzzy Cognitive Maps and their Applications in Medical Diagnostics.
http://www.cbmi.cvut.cz/lab/publikace/30/Vys98_11.doc.

In diagnostics of the depression, psychiatrists lack an objective knowledge about patient state.

Except for very strong depressions no significant changes of the physiological parameters are measurable.

Almost all information about patient mental state is obtained in verbal form on the base of conversation with the patient.

Due to this fact, data are vague, uncertain and often inconsistent.

Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 4: Use of FCM in medical diagnostics - cont.

Contemporary most popular approach to the etiopathogenesis of a depression is based on cognitive-behavioral theory of depression.

This theory assumes, that incorrect cognitive processing of information coming from an environment causes the depression.

Patient's interpretation of events in this environment is distorted, and this misinterpretation influenced his behaviour. They are different "negative ideas", "automatic ideas", activation of the disfunction rules, etc.

A degree of the depression is usually evaluated by therapist with help of the Beck's scale. It is pseudo-quantification based on complicated questionnaire.

Patient answers expressing his attitudes to the different problems are evaluated by means of the fourdegree scale and their sum, final score can be considered as the degree of depressive mood. It enables of course to estimate the degree of immediate depressive mood. But is doesn't say anything about way leading to this state (which mental states or moods were predecessors of this instantaneous mood), and it doesn't say anything about prognosis of future states or moods.

Automatic and negative ideas have complicated dynamics depending on the preceding states.

Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 4: Use of FCM in medical diagnostics - cont.

The submitted approach based on the fuzzy cognitive maps enables to catch the mentioned dynamics. A first step is to classify different moods into a set of qualitatively distinguished and verbally labeled categories.

Each category (specific mood), is determined with help of specific factors e.g. possibility of concentration, efficiency, feeling of meaningfulness of patients work, feeling of understanding of his environment etc.

They are the same or very similar factors like in questionnaire of the Beck's scale.

Now these categories may be considered like terms of linguistic variable "mood". It means that they are fuzzy sets defined on factor space.

During the time patient passes from one mood to another.

Transition depends on previous state and on instantaneous influences from the environment. It can be investigated by interviewing the patient and be vividly depicted with help of the cognitive map.

Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 4: Use of FCM in medical diagnostics - cont.

The nodes of the map correspond with states (moods) and edges correspond with transitions from one state to another.

The cognitive map is constructed intuitively according to patient's own description of his feelings and self evaluation.

This cognitive map provides much more information about patient mental states then simple estimating of instantaneous degree of depressive mood.

We can see, that some transitions are more frequent than others, and that some transitions are caused or inhibited by influences from patient's environment.

On the other hand, cycles in the graph of the cognitive map can be recognized.

These cycles correspond with "automatic ideas", and under the certain conditions they may behave as attractors in factor space.

This description provides a deeper understanding of dynamic of the patient thinking, his misinterpretation of "inputs" leading him to the undesirable cycles.

It enables to find such "inputs" which remove him safely far from attracting areas of these cycles and to prepare base for effective psychotherapy.

Applications of Fuzzy Cognitive Maps – cont.

APPLICATION 4: Use of FCM in medical diagnostics - cont.

Any patient can distinguish a finite number of moods. According to his verbal description we can construct fuzzy cognitive map.

This FCM can be considered as a graph of the state transition structure of some fuzzy finite automaton.

Analyzing this FCM we could obtain its input and output alphabet, set of inner states and the state transition and output relations.

Having this more formal description, we can analyze more correctly boundaries of attracting areas and we can simulate some therapeutical procedures.

Thus we see FCMs can be used to study several medical problems and especially for medical areas as important as psychotherapy where diagnostics plays a major role.

Neutrosophic Graphs

We introduce the notion of neutrosophic graphs, which is basically needed to obtain neutrosophic cognitive maps, which will be nothing but directed neutrosophic graphs.

Similarly, neutrosophic relational maps will also be directed neutrosophic graphs.

It is no coincidence that graph theory has been independently discovered many times since it may quite properly be regarded as an area of applied mathematics.

The subject finds its place in the work of Euler. Subsequent rediscoveries of graph theory were by Kirchhoff and Cayley. Euler (1707-1782) became the father of graph theory as well as topology when in 1936 he settled a famous unsolved problem in his day called the Konigsberg Bridge Problem.

Psychologist Lewin proposed in 1936 that the life space of an individual be represented by a planar map.

His view point led the psychologists at the Research center for Group Dynamics to another psychological interpretation of a graph in which people are represented by points and interpersonal relations by lines.

Such relations include love, hate, communication and power.

In fact it was precisely this approach which led the author to a personal discovery of graph theory, aided and abetted by psychologists L. Festinger and D. Cartwright.

Neutrosophic Graphs – cont.

Here it is pertinent to mention that the directed graphs of an FCMs or FRMs are nothing but the psychological inter-relations or feelings of different nodes; but it is unfortunate that in all these studies the concept of indeterminacy was never given any place, so in this chapter for the first time we will be having graphs in which the notion of indeterminacy i.e. when two vertex should be connected or not is never dealt with.

If graphs are to display human feelings then this point is very vital for in several situations certain relations between concepts may certainly remain an indeterminate.

The world of theoretical physics discovered graph theory for its own purposes. In the study of statistical mechanics by Uhlenbeck the points stands for molecules and two adjacent points indicate nearest neighbor interaction of some physical kind, for example magnetic attraction or repulsion. But it is forgotten in all these situations we may have molecule structures which need not attract or repel but remain without action or not able to predict the action for such analysis we can certainly adopt the concept of neutrosophic graphs.

In a similar interpretation by Lee and Yang the points stand for small cubes in Euclidean space where each cube may or may not be occupied by a molecule. Then two points are adjacent whenever both spaces are occupied.

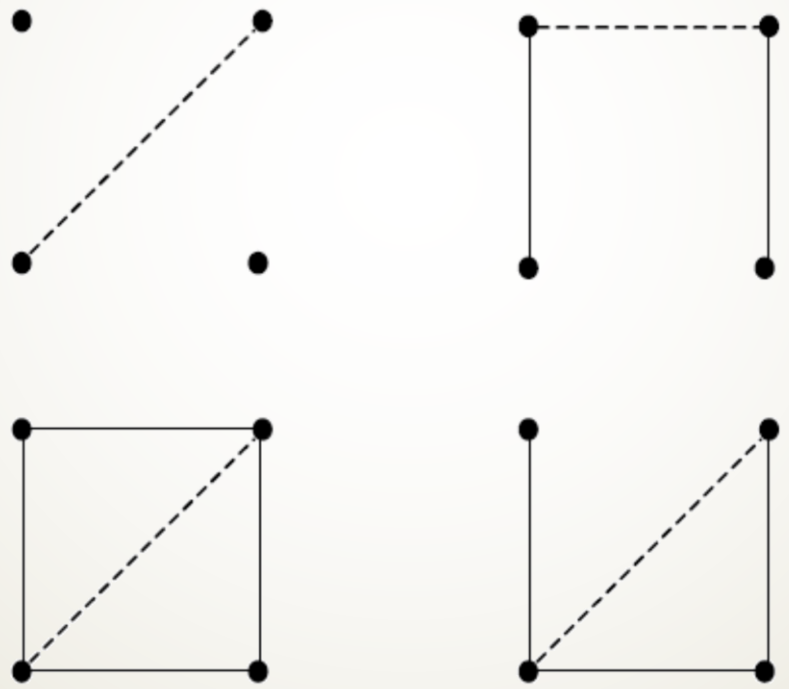
Feynmann proposed the diagram in which the points represent physical particles and the lines represent paths of the particles after collisions. Just at each stage of applying graph theory we may now feel the neutrosophic graph theory may be more suitable for application.

Now we proceed on to define the neutrosophic graph.

Neutrosophic Graphs – cont.

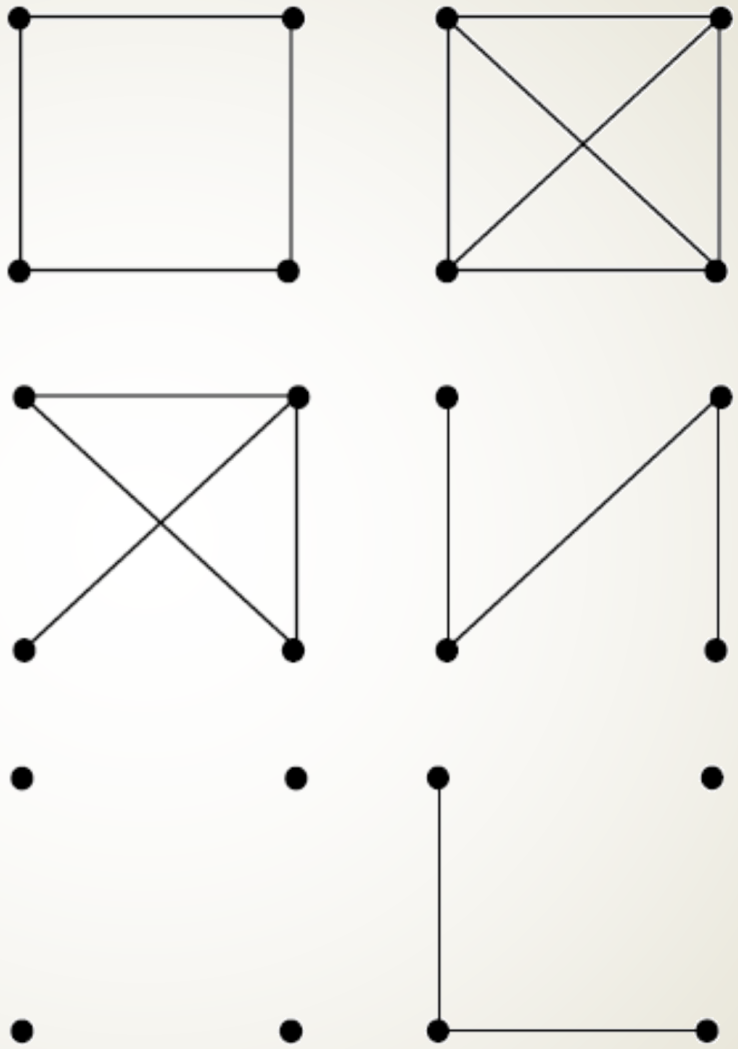
DEFINITION: A neutrosophic graph is a graph in which at least one edge is an indeterminacy denoted by dotted lines.

NOTATION: The indeterminacy of an edge between two vertices will always be denoted by dotted lines.



Example 1: Neutrosophic graphs.

Neutrosophic Graphs – cont.



Example 2: All graphs in general are not neutrosophic graphs!

Neutrosophic Cognitive Maps (NCMs)

Neutrosophic Cognitive Maps (NCMs) are a generalization of Fuzzy Cognitive Maps (FCMs).

The notion of Fuzzy Cognitive Maps (FCMs) are fuzzy signed directed graphs.

The directed edge e_{ij} from causal concept C_i to concept C_j measures how much C_i causes C_j. The time varying concept function $C_i(t)$ measures the non negative occurrence of some fuzzy event, perhaps the strength of a political sentiment, historical trend or opinion about some topics like child labor or school dropouts etc.

FCMs model the world as a collection of classes and causal relations between them.

The edge e_{ij} takes values in the fuzzy causal interval $[-1, 1]$ ($e_{ij} = 0$ indicates no causality, $e_{ij} > 0$ indicates causal increase; that C_j increases as C_i increases and C_j decreases as C_i decreases, $e_{ij} < 0$ indicates causal decrease or negative causality C_j decreases as C_i increases or C_j, increases as C_i decreases.

Simple FCMs have edge value in {-1, 0, 1}.

Thus if causality occurs it occurs to maximal positive or negative degree.

Neutrosophic Cognitive Maps (NCMs) – cont.

It is important to note that e_{ij} measures only absence or presence of influence of the node C_i on C_j but till now any researcher has not contemplated the indeterminacy of any relation between two nodes C_i and C_j.

When we deal with unsupervised data, there are situations when no relation can be determined between some two nodes.

So we try to introduce the indeterminacy in FCMs, and we choose to call this generalized structure as Neutrosophic Cognitive Maps (NCMs).

In our view this will certainly give a more appropriate result and also caution the user about the risk of indeterminacy.

Now we proceed on to define the concepts about NCMs.

DEFINITION: A Neutrosophic Cognitive Map (NCM) is a neutrosophic directed graph with concepts like policies, events etc. as nodes and causalities or indeterminates as edges. It represents the causal relationship between concepts.

Neutrosophic Cognitive Maps (NCMs) – cont.

Let $C_1, C_2, \ldots, C_n$ denote n nodes, further we assume each node is a neutrosophic vector from neutrosophic vector space V.

So a node C_i will be represented by $(x_1, \ldots, x_n)$ where x_k's are zero or one or I (I is the indeterminate introduced above) and $x_k = 1$ means that the node C_k is in the on state and $x_k = 0$ means the node is in the off state and $x_k = I$ means the nodes state is an indeterminate at that time or in that situation.

Let C_i and C_j denote the two nodes of the NCM.

The directed edge from C_i to C_j denotes the causality of C_i on C_j called connections.

Every edge in the NCM is weighted with a number in the set $\{-1, 0, 1, I\}$.

Let e_{ij} be the weight of the directed edge $C_i C_j$, $e_{ij} \in \{-1, 0, 1, \mathbf{I}\}$.

$e_{ij} = 0$ if C_i does not have any effect on C_j, $e_{ij} = 1$ if increase (or decrease) in C_i causes increase (or decreases) in C_j, $e_{ij} = -1$ if increase (or decrease) in C_i causes decrease (or increase) in C_j.

$e_{ij} = I$ if the relation or effect of C_i on C_j is an indeterminate.

Neutrosophic Cognitive Maps (NCMs) – cont.

Example: The child labor problem prevalent in India is modeled in this example using NCMs.

Let us consider the child labor problem with the following conceptual nodes

C1 - Child Labor

C2 - Political Leaders

C3 - Good Teachers

C4 - Poverty

C5 - Industrialists

C6 - Public practicing/encouraging Child Labor

C7 - Good Non-Governmental Organizations (NGOs)

C1 - Child labor, it includes all types of labor of children below 14 years which include domestic workers, rag pickers, working in restaurants / hotels, bars etc. (It can be part time or fulltime).

Neutrosophic Cognitive Maps (NCMs) – cont.

Example: The child labor problem prevalent in India is modeled in this example using NCMs - cont.

C2 - We include political leaders with the following motivation: Children are not vote banks so political leaders are not directly concerned with child labor but they indirectly help in the flourishing of it as industrialists who utilize child laborers or cheap labor are the decision makers for the winning or losing of the political leaders. Also industrialists financially control political interests. So we are forced to include political leaders as a node in this problem.

C3 - Teachers are taken as a node because mainly school dropouts or children who have never attended the school are child laborers. So if the motivation by the teacher is very good, there would be less school dropouts and therefore there would be a decrease in child laborers.

C4 - Poverty which is the most responsible reason for child labor.

C5 - Industrialists – when we say industrialists we include one and all starting from a match factory or beedi factory, bars, hotels etc.

C6 - Public who promote child labor as domestic servants, sweepers etc.

C7 - We qualify the NGOs as good for some NGOs may not take up the issue fearing the rich and the powerful. Here "good NGOs" means NGOs who try to stop or prevent child labor.

Neutrosophic Cognitive Maps (NCMs) – cont.

Example: The child labor problem prevalent in India is modeled in this example using NCMs - cont.

In the following slides, we give the directed graph as well as the neutrosophic graph of two experts.

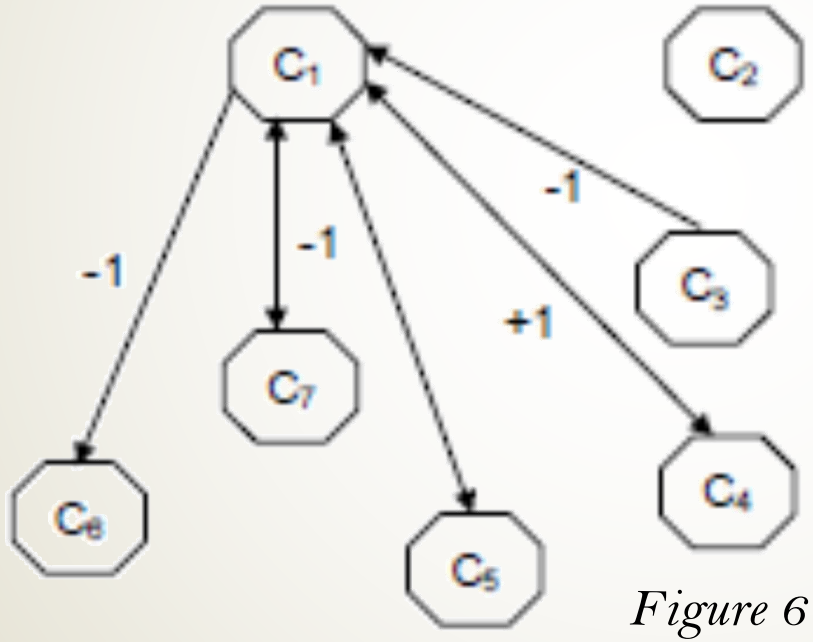


Figure 6

Figure 6 gives the directed graph with C_1, C_2, …, C_7 as nodes and Figure 7 next slides gives the neutrosophic directed graph with the same nodes.

Neutrosophic Cognitive Maps (NCMs) – cont.

Example: The child labor problem prevalent in India is modeled in this example using NCMs - cont.

The connection matrix E related to the graph in *Figure 6* is given below:

$$E = \begin{bmatrix} 0 & 0 & 0 & 1 & 1 & 1 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}.$$

According to this expert no connection however exists between political leaders and industrialists.

In the following, we reformulate a different format of the questionnaire where we permit the expert to give answers like the relation between certain nodes is indeterminable or not known.

Neutrosophic Cognitive Maps (NCMs) – cont.

Example: The child labor problem prevalent in India is modeled in this example using NCMs - cont.

Now based on the expert's opinion also about the notion of indeterminacy we obtain the following neutrosophic directed graph:

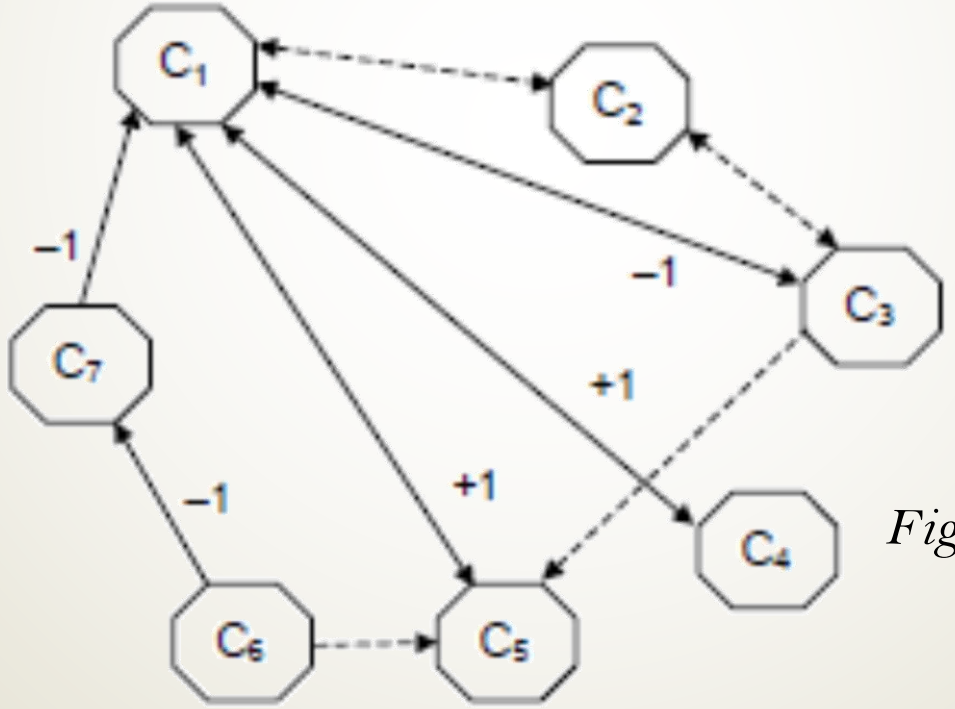


Figure 7

Neutrosophic Cognitive Maps (NCMs) – cont.

Example: The child labor problem prevalent in India is modeled in this example using NCMs - cont.

The corresponding neutrosophic adjacency matrix $N(E)$ related to the neutrosophic directed graph (*Figure 6*) is given below:

$$N(E) = \begin{bmatrix} 0 & I & -1 & 1 & 1 & 0 & 0 \\ I & 0 & I & 0 & 0 & 0 & 0 \\ -1 & I & 0 & 0 & I & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & I & 0 & -1 \\ -1 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Suppose we take the state vector $A_1 = (1\ 0\ 0\ 0\ 0\ 0\ 0)$. We will see the effect of A_1 on E and on $N(E)$.

$$A_1E = (0\,0\,0\,1\,1\,1\,-1) \rightarrow (1\,0\,0\,1\,1\,1\,0) = A_2$$
$$A_2E = (2\,0\,0\,1\,1\,1\,0) \rightarrow (1\,0\,0\,1\,1\,1\,0) = A_3 = A_2.$$

Neutrosophic Cognitive Maps (NCMs) – cont.

Example: The child labor problem prevalent in India is modeled in this example using NCMs - cont.

Thus child labor flourishes with parents' poverty and industrialists' action.

Public practicing child labor also flourish but good NGOs are absent in such a scenario.

The state vector gives the fixed point.

Now we find the effect of $A_1 = (1\ 0\ 0\ 0\ 0\ 0\ 0)$ on $N(E)$.

$$A_1N(E) = (0\ I\ -1\ 1\ 1\ 0\ 0) \rightarrow (1\ I\ 0\ 1\ 1\ 0\ 0) = A_2$$
$$A_2N(E) = (I+2, I, -1+I, 1\ 1\ 0\ 0) \rightarrow (1\ I\ 0\ 1\ 1\ 0\ 0) = A_2$$

Thus $A_2 = (1\ I\ 0\ 1\ 1\ 0\ 0)$, according to this expert the increase or the on state of child labor certainly increases with the poverty of parents and other factors are indeterminate to him.

This mainly gives the indeterminates relating to political leaders and teachers in the neutrosophic cognitive model and the parents poverty and Industrialist become to on state.

Neutrosophic Cognitive Maps (NCMs) – cont.

Example: The child labor problem prevalent in India is modeled in this example using NCMs - cont.

However, the results by FCM give as if there is no effect by teachers and politicians for the increase in child labor. Actually the increase in school dropout increases the child labor hence certainly the role of teachers play a part. At least if it is termed as an indeterminate one would think or reflect about their (teachers) effect on child labor.

Also the node the role played by political leaders has a major part; for if the political leaders were stern about stopping the child labor, certainly it cannot flourish in the society. They are ignored for two reasons: First, if children were vote banks certainly their position would be better. The second reason is, industrialists who practice child labor, are a main source of help to politicians, and their victory/defeat depends on their (financial) support so the causes for politicians ignoring child labor is two-fold.

Now we seek the opinion of another expert who is first asked to give a FCM model and then a provocative questionnaire discussing about the indeterminacy of relation between nodes is suggested and he finally gives a neutrosophic version of his ideas.

Neutrosophic Cognitive Maps (NCMs) – cont.

Example: The child labor problem prevalent in India is modeled in this example using NCMs - cont.

Figure 8 is the directed graph of the expert.

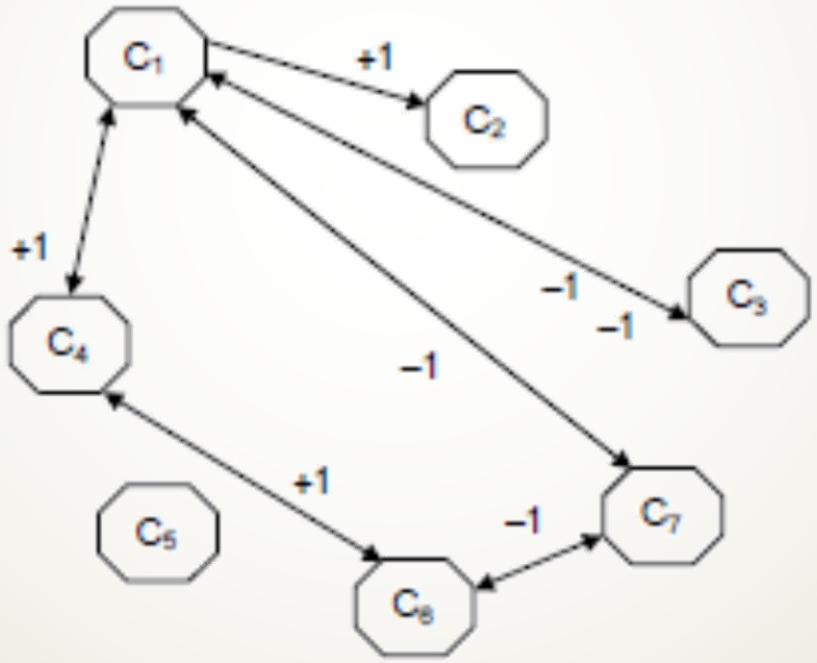


Figure 8

Neutrosophic Cognitive Maps (NCMs) – cont.

Example: The child labor problem prevalent in India is modeled in this example using NCMs - cont.

The related connection matrix E_1 is as follows:

$$E_1 = \begin{bmatrix} 0 & 1 & -1 & 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & -1 \\ -1 & 0 & 0 & 0 & 0 & -1 & 0 \end{bmatrix}.$$

Take $A_1 = (1\ 0\ 0\ 0\ 0\ 0\ 0)$ the effect of A_1 on the system E_1 is

$$\begin{array}{lcccccl} A_1E_1 & = & (0\ 1\ -1\ 1\ 0\ 0\ -1) & \rightarrow & (1\ 1\ 0\ 1\ 0\ 0\ 0) & = & A_2 \\ A_2E_2 & = & (1\ 1\ -1\ 1\ 0\ 1\ -1) & \rightarrow & (1\ 1\ 0\ 1\ 0\ 1\ 0) & = & A_3 \\ A_3E_2 & = & (1\ 1\ -1\ 2\ 0\ 1\ -2) & \rightarrow & (1\ 1\ 0\ 1\ 0\ 1\ 0) & = & A_4 = A_3. \end{array}$$

Neutrosophic Cognitive Maps (NCMs) – cont.

Example: The child labor problem prevalent in India is modeled in this example using NCMs - cont.

Thus according to this expert child labor has direct effect on political leaders, no effect on good teachers, effect on poverty and industrialists and no-effect on the public who encourage child labor; and good NGOs.

The same person was now put with the neutrosophic questions i.e. terms like “can you find any relation between the nodes or are you not in apposition to decide any relation between two nodes and so on”; so that a idea of indeterminacy is introduced to them.

Now the neutrosophic directed graph is drawn using this experts opinion given in *Figure 9*.

Neutrosophic Cognitive Maps (NCMs) – cont.

Example: The child labor problem prevalent in India is modeled in this example using NCMs - cont.

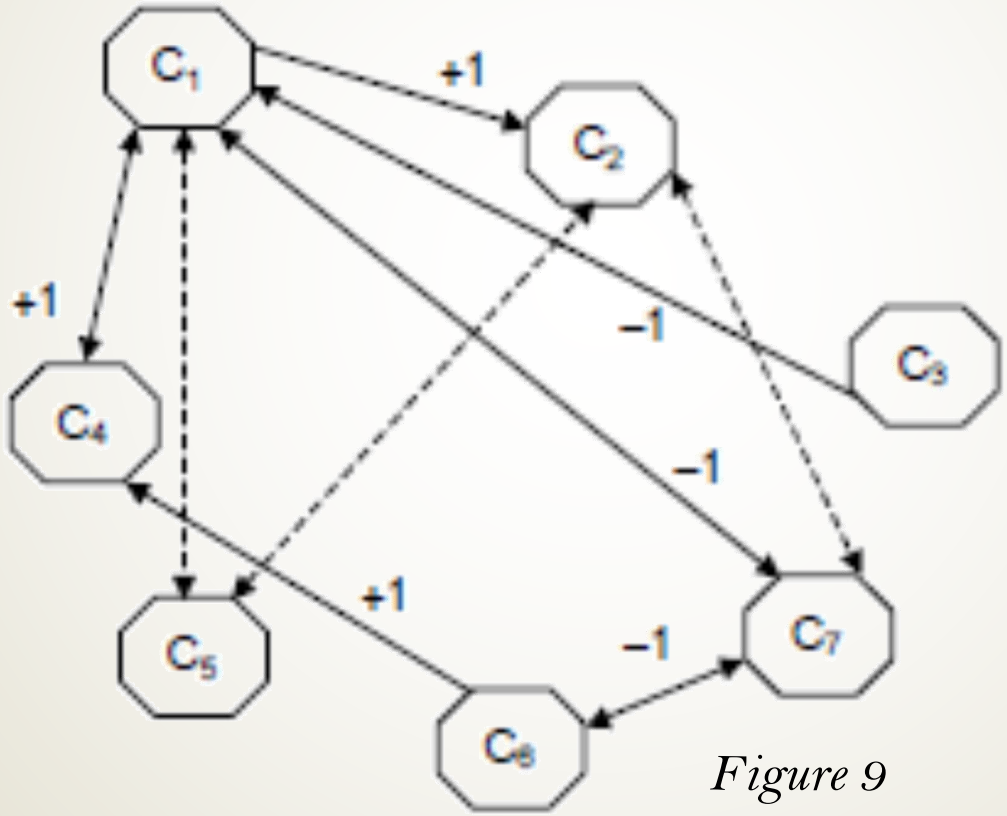


Figure 9

Neutrosophic Cognitive Maps (NCMs) – cont.

Example: The child labor problem prevalent in India is modeled in this example using NCMs - cont.

The corresponding neutrosophic connection matrix $N(E_1)$ is as follows:

$$N(E_1) = \begin{bmatrix} 0 & 1 & -1 & 1 & I & 0 & -1 \\ 0 & 0 & 0 & 0 & I & 0 & I \\ -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ I & I & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & -1 \\ -1 & 0 & 0 & 0 & 0 & -1 & I \end{bmatrix}.$$

Neutrosophic Cognitive Maps (NCMs) – cont.

Example: The child labor problem prevalent in India is modeled in this example using NCMs - cont.

Suppose $A_1 = (1, 0, 0, 0, 0, 0, 0)$ is the state vector whose effect on the neutrosophic system $N(E_1)$ is to be considered.

$A_1N(E_1) = (0\ 1\ -1\ 1\ I\ 0\ -I) \rightarrow (1\ 1\ 0\ 1\ I\ 0\ 0) = A_2$

$A_2N(E_1) = (1+I, 1+I, -1, 1, 2I+1, 0, -1+I) \rightarrow (1\ 1\ 0\ 1\ 1\ 0\ 0) = A_3$

$A_3N(E_1) = (1+I, 1+I, -1, 2\ I+1\ 0\ -1+I) \rightarrow (1\ 1\ 0\ 1\ 1\ 0\ 0) = A_4.$

We see $A_2 = A_3$.

But according to the NCM when the conceptual node child labor is on it implies that the cause of it is political leaders, poverty and industrialists participation by employing children as laborers.

The audience is expected to compare this NCM with FCMs for the same problem, as we have now indicated how a NCM works.

Neutrosophic Cognitive Maps (NCMs) – cont.

Another Example: Application of NCM to study the Hacking of e-mail by students.

One of the major problems of today's world of information technology that is faced by one and all is; How safe are the messages that are sent by e-mail? Is there enough privacy?

For if a letter is sent by post one can by certain say that it cannot be read by any other person, other than the receiver.

Even tapping or listening (over hearing) of phone calls from an alternate location / extension is only a very uncommon problem.

However compared to these modes of communication even though e-mail guarantees a lot of privacy it is a highly common practice to hack e-mail.

Hacking is legally a cyber crime but is also one of the crimes that does not leave any trace.

Hacking of another persons e-mail account can be carried out for a variety of purposes to study the factors, which are root-causes of such crimes we use NCM to analyse them.

Neutrosophic Cognitive Maps (NCMs) – cont.

Another Example: Application of NCM to study the Hacking of e-mail by students - cont.

The following nodes are taken as the conceptual nodes.

C1 - Curiosity
C2 - Professional rivalry
C3 - Jealousy/ enmity
C4 - Sexual satisfaction
C5 - Fun/pastime
C6 - To satisfy ego
C7 - Women students
C8 - Breach of trust.

However more number of conceptual nodes can be added as felt by the expert or the investigator.

Neutrosophic Cognitive Maps (NCMs) – cont.

Another Example: Application of NCM to study the Hacking of e-mail by students - cont.

The neutrosophic directed graph as given by an expert is given in *Figure* below.

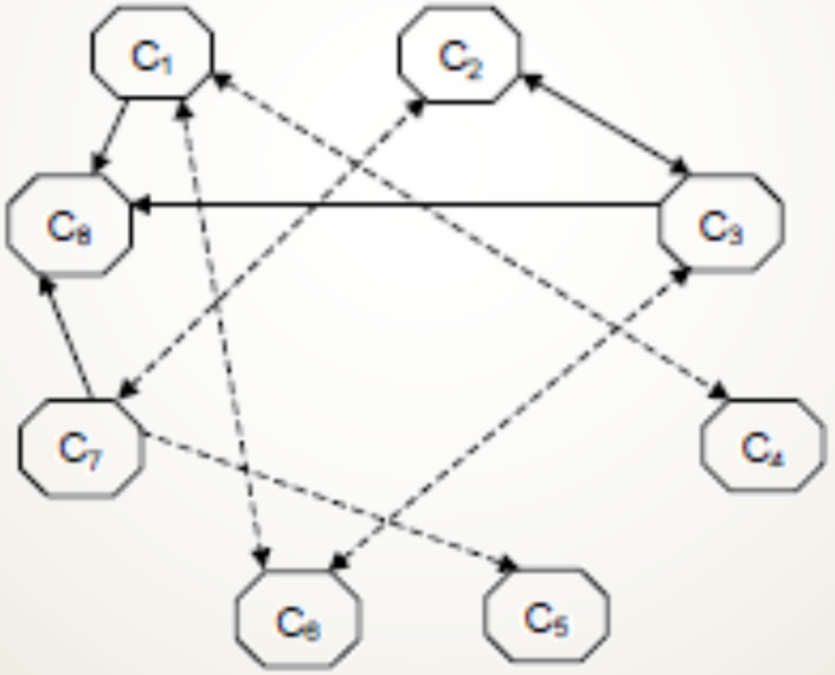


Figure 10

Neutrosophic Cognitive Maps (NCMs) – cont.

Another Example: Application of NCM to study the Hacking of e-mail by students - cont.

The corresponding neutrosophic connection matrix $N(E)$ is as follows:

$$N(E) = \begin{bmatrix} 0 & 0 & 0 & I & 0 & I & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 & I & 0 \\ 0 & 1 & 0 & 0 & 0 & I & 0 & 1 \\ I & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ I & 0 & I & 0 & 0 & 0 & 0 & 0 \\ 0 & I & 0 & 0 & I & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}.$$

Neutrosophic Cognitive Maps (NCMs) – cont.

Another Example: Application of NCM to study the Hacking of e-mail by students - cont.

Suppose we take the instantaneous state vector $A_1 = (0\ 0\ 0\ 0\ 0\ 0\ 1\ 0)$, women students node is in the on state then the effect of A_1 on the neutrosophic system $N(E)$ is given by

$$
\begin{array}{lcccl}
A_1N(E) & = & (0\ I\ 0\ 0\ I\ 0\ 0\ 1) & \rightarrow & (0\ I\ 0\ 0\ I\ 0\ 1\ 1) = A_2 \\
A_2N(E) & = & (0\ I\ I\ 0\ I\ 0\ I\ 1) & \rightarrow & (0\ I\ I\ 0\ I\ 0\ 1\ 1) = A_3 \\
A_3N(E) & = & (0\ I\ I\ 0\ I\ I\ I\ 1+I) & \rightarrow & (0\ I, I, 0, I, I, 1, 1) = A_4 \\
A_4N(E) & = & (I, I\ I\ 0\ I\ I\ I\ I+1) & \rightarrow & (I\ I\ I\ 0\ I\ I\ 1\ 1) = A_5 \\
A_5N(E) & = & (I\ I\ I\ 0\ I\ I\ I\ 1) & \rightarrow & (I\ I\ I\ 0\ I\ I\ 1\ 1) = A_6 = A_5.
\end{array}
$$

So in case the node "women students" is in the on state node we see curiosity is an indeterminate, professional rivalry is an indeterminate, jealousy/ enmity is an indeterminate sexual satisfaction is in the off state, fun/ pastime is an indeterminate, to satisfy ego is an indeterminate and breach of trust is in the on state whereas if the 'I's are removed and $N(E)$ is used as a usual FCM matrix then the effect $B_1 = (0\ 0\ 0\ 0\ 0\ 0\ 1\ 0)$ in the on state when passed through the system we get $B = (0\ 0\ 0\ 0\ 1\ 0\ 1\ 1)$ implies to satisfy ego becomes the on state and Breach of trust is in the on state. Thus we see other sates are in the off state.

The reader is expected to work with other coordinates and compare with FCMs which is got by replacing all Is in the neutrosophic connection matrix $N(E)$ by 0.

Applications of Neutrosophic Cognitive Maps.

APPLICATION 1: Modeling Supervisory Systems using NCM

The concept of NCM can be used in modeling of supervisory systems in the design of hybrid models for complex systems wherever the concept of indeterminacy play a role in that model. This model "The challenge of modeling supervisory systems using fuzzy cognitive maps" as carried out by C. Stylios et al does not lend itself for the application of NCM as we see their does not exist an indeterminacy when the conceptual nodes are taken as the state of the valve closed open or partially closed.

Stylios, C.D., and P.P. Groumpos. The Challenge of Modeling Supervisory Systems using Fuzzy Cognitive Maps, J. of Intelligent Manufacturing, 9 (1998) 339-345.

However when we assume the valve is closed it may happen that there is some leakage in the valve or it is not closed properly in such case certainly we suggest the FCM structure can be modified and the NCM model can be implemented so that the results can be more accurate and when indeterminacy occurs we can have a doubt about the specific gravity of the liquid that is produced during the mixing when the measured specific gravity lies in a specified range.

Applications of Neutrosophic Cognitive Maps - cont.

APPLICATION 1: Modeling Supervisory Systems using NCM – cont.

Another indeterminacy that may occur is that in the events 1 to 8 listed in Stylios and Groumpos it may so happen when the variation /amount of liquid in the tank is taken the six liquid filling the pipe wastage of liquid while operating the valves etc should be given enough representation or all these can be kept as an indeterminacy and work should be carried out so that the results obtained under this model happens to be better than the existing ones.

Stylios, C.D., and P.P. Groumpos. The Challenge of Modeling Supervisory Systems using Fuzzy Cognitive Maps, J. of Intelligent Manufacturing, 9 (1998) 339-345.

The audience is expected to develop this model using NCM.

Applications of Neutrosophic Cognitive Maps - cont.

APPLICATION 2: Design of Hybrid Models for Complex Systems: a NCM Approach

FCM is applied in the Hybrid Models of Complex Systems.

Hadjiski, M. B., Christova, N.G., and Groumpos, P.P. Design of hybrid models for complex systems. http://www.erudit.de/erudit/events/esit99/12773_p.pdf

We now apply NCM to model the Complex Systems.

By incorporating neutrosophic principles into a neural network we feel that the edge weight e_{ij} can also be indeterminate.

So even the simple NCMs (i.e. edge weights $e_{ij} \in \{-1, 1, 0\ I\}$ act as asymmetrical networks of threshold or continuous neurons and converge to limit cycles.

Applications of Neutrosophic Cognitive Maps - cont.

APPLICATION 2: Design of Hybrid Models for Complex Systems: a NCM Approach – cont.

It is suggested to involve NCM which best utilize existing experience in the operation of the system and are capable in modeling the behaviour of complex systems, as NCMs seems to be a useful method in complex system modeling and control which will help the designer of a system in decision analysis.

The audience is expected to model complex systems using NCM working in an analogous way of Hadjiski at al., which is direct and easily anyone can do it as a matter of routine; and it is suggested to the adueince as a piece of research.

Hadjiski, M. B., Christova, N.G., and Groumpos, P.P. Design of hybrid models for complex systems. http://www.erudit.de/erudit/events/esit99/12773_p.pdf

Applications of Neutrosophic Cognitive Maps - cont.

APPLICATION 3: Use of NCM in Robotics

While it has been argued that FCMs are preferred for usage in robotics and applications of intimate technologies, owing to their ability to handle contradictory inputs, NCMs would be the more viable tool, for not only are they capable of handling contradictory inputs, but they can also handle indeterminacy.

Further FCMs have been used to model the Office Plant #1 to analyse the types of emails.

Bohlen, M. and M. Mateas. Office Plant #1.

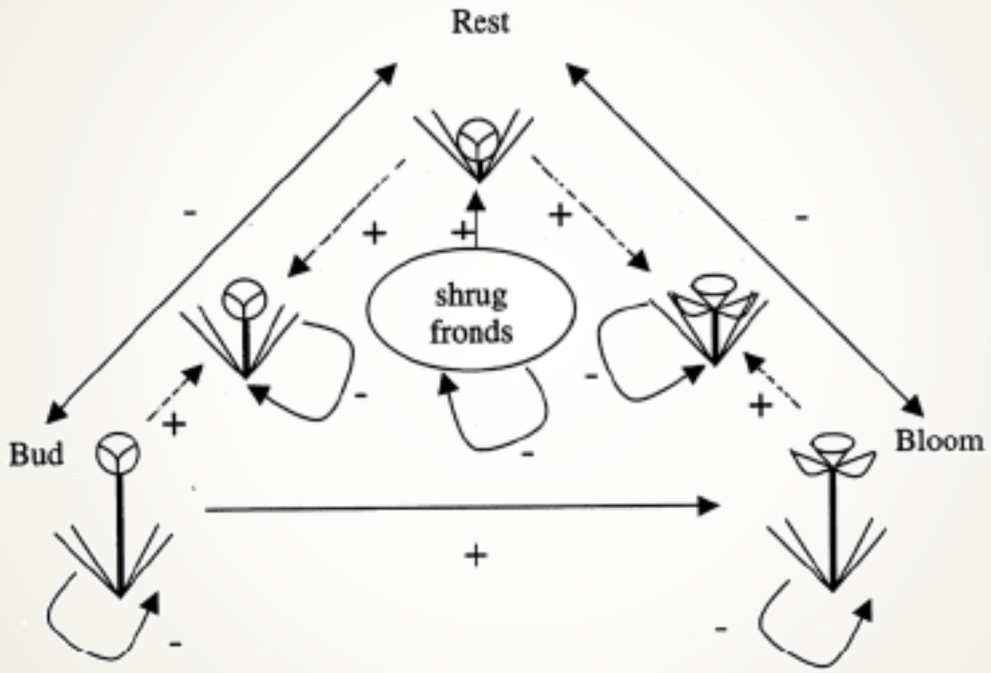
http://www.acsu.buffalo.edu/~mrbohlen/pdf/leonardo.pdf

It is once again left as an exercise for the audience to use NCM in the place of FCM. For categorically one cannot always divide the e-mails as official / non official, friendly / business like and so on for some can be termed as indeterminate, semi-friendly and semiofficial or so on and so forth.

So NCM can be adopted in mobile robots like Office Plant #1 and the study can be carried out as a maiden effort. A description of use of FCM was given above.

Applications of Neutrosophic Cognitive Maps - cont.

APPLICATION 3: Use of NCM in Robotics – cont.



For example we see at each stage the relation would be indeterminate if the email received has an over-lapping attributes in which case the section of the node may be indeterminate. Thus in the behaviour of the office plant, the dotted arrows ought to be adopted in situations where there is indeterminacy.

Applications of Neutrosophic Cognitive Maps - cont.

APPLICATION 4: Use of NCMs to find the driving speed in any one in freeway

Brubaker used FCMs to create a model to find ones speed when driving in a California freeway.

Brubaker, D. Fuzzy Cognitive Maps, EDN ACCESS, 11 April 1996.
http://www.e-insite.net/ednmag/archives/1996/041196/08column.htm
Brubaker, D. More on Fuzzy Cognitive Maps, EDN ACCESS, 25 April 1996.
http://www.e-insite.net/ednmag/archives/1996/042596/09column.htm

Thus FCM plays a major role in the study and analysis of transportation problem of all kind, for transportation problems are basically problems of decision-making. In our opinion, NCM can also be used to arrive at better results.

The concepts or nodes of the FCM are bad weather, freeway congestion, auto accidents, patrol frequency, own risk aversion, impatience and attitude. Now if these are taken as nodes certainly we can have pairs of nodes for which the relation is indeterminate, for the concept of impatience and attitude with other concepts like bad weather or free way congestion and speed of others is an indeterminate in itself.

Applications of Neutrosophic Cognitive Maps - cont.

APPLICATION 4: Use of NCMs to find the driving speed in any one in freeway – cont.

For fearing the bad weather one may be impatient and drive fast due to the fear that the weather may become worst or some other may fear bad weather (and consequent accidents) and be obsessed with fear and drive slow; the minute the nature of impatience or fear dominates a person certainly one cannot predict the speed, hence a lot of uncertainty and indeterminacy is involved.

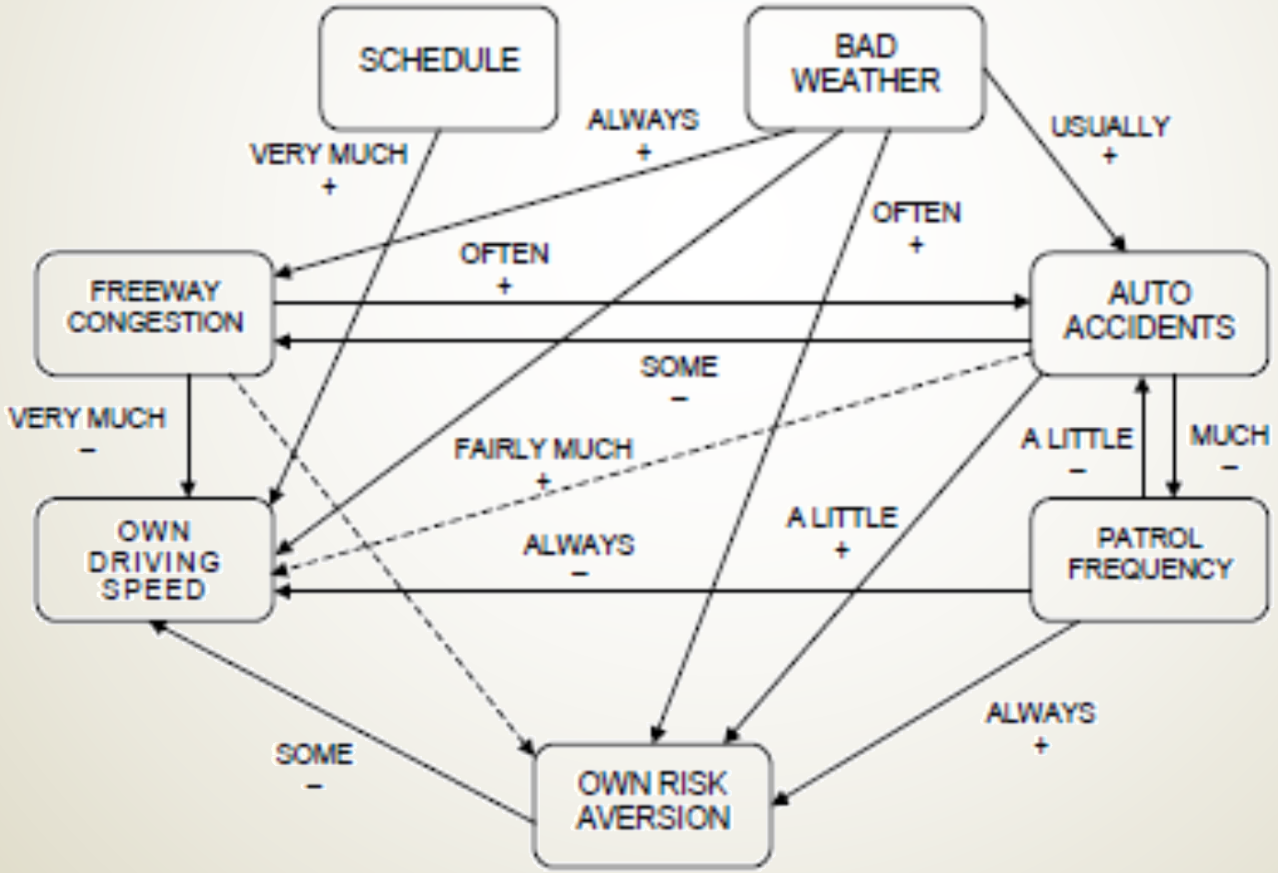
So the adaptation of NCM may yield a better understanding and modeling of the problem than FCMs.

Thus we request the audience to model this problem using NCM and compare it when only FCM is applied.

For a slight suggestion of how to go about with this NCM, we have for the reader's sake provided a possible NCM graph in *Figure* next slide.

Applications of Neutrosophic Cognitive Maps - cont.

APPLICATION 4: Use of NCMs to find the driving speed in any one in freeway – cont.



Applications of Neutrosophic Cognitive Maps - cont.

APPLICATION 4: Use of NCMs to find the driving speed in any one in freeway – cont.

As our main aim is to motivate researchers to use NCMs in place of FCMs whenever applicable and apply them to real world problems, we just give justification for the use of NCM and leave the work of constructing an NCM model to the audience.

Even in this problem it is not only speed of one who drives but also several others factors like the speed of others, congestion etc. may or may not play an indeterminable role.

Accidents are very common in the countries like India, where many other factors like bad roads; reckless driving by others; drunken driving etc. wreak havoc on the number of accident deaths.

We can say in conclusion that problems related to traffic and transportation can be very efficiently handled with tools like the FCM and the NCM.

Applications of Neutrosophic Cognitive Maps - cont.

APPLICATION 5: Application of NCM in Medical Diagnostics

In diagnostics of the depression psychiatrist has a lack of an objective knowledge about patient state.

Except for very strong depressions no significant changes of the physiological parameters are measurable.

Almost all information about patient mental state is obtained in verbal form on the basis of conversation with the patient.

Due to this fact, data are vague, uncertain, inconsistent and also indeterminable.

The most popular modern approach to the etiopathogenesis of a depression is based on cognitive-behavioral theory of depression.

This theory assumes that "the depression is caused by incorrect cognitive processing of information coming from an environment".

Applications of Neutrosophic Cognitive Maps - cont.

APPLICATION 5: Application of NCM in Medical Diagnostics – cont.

Description of this problem and use of FCM is given by Vysoky and we have dealt with it in an earlier section.

Vysoký, P. Fuzzy Cognitive Maps and their Applications in Medical Diagnostics.
http://www.cbmi.cvut.cz/lab/publikace/30/Vys98_11.doc

We feel that use of NCM in the place of FCM will yield better results.

This task of working with NCM to study medical diagnostics is left for the interested reader as a lot of indeterminacy is involved: for instance it is well known that certain types of food may trigger depression, meeting some people can cause depression, and several times mood-swings are connected with changes in the weather.

Above all, gender, age, social status and the type of (other) diseases may also be factors, which help us to understand depression.

Applications of Neutrosophic Cognitive Maps - cont.

APPLICATION 6: Application of NCMs in Diagnosis and Study of Specific Language Impairment

Georgopoulous et al. have used FCMs in the diagnosis of specific language impairment.

Georgopoulous, V.C., G.A.Malandrak and C.D.Stylios. A Fuzzy Cognitive Map Approach to Differential Diagnosis of Specific Language Impairment, Artificial Intelligence in Medicine, 679 (2002) 1-18

We use the concept of NCMs i.e. indeterminacy of nodes and the corresponding neutrosophic matrix certainly the result would be more sensitive for the following reasons:

- The language impairment may at times be indeterminate when the child communicates with its parents, but refuses to communicate with strangers, or in cases where owing to fear the child may not communicate with teachers and in such cases of behavioural peculiarities, the degrees of indeterminacy become greater.

Applications of Neutrosophic Cognitive Maps - cont.

APPLICATION 6: Application of NCMs in Diagnosis and Study of Specific Language Impairment

- Another factor is the language factor, in which the child is taught to communicate.

  For in India, owing to a multiplicity of languages, children often are brought up to speak a language at home which is different from the lingua franca of the world outside.

  In such cases, the relation between nodes may remain as indeterminate.

- Other such indeterminacy can also occur which may involve the circumstance and time.

Thus it is left for the audience to adopt NCM and model the specific language impairment problem and compare it when FCM is applied to the same problem by replacing I by 0.

Neutrosophic Cognitive Maps versus Fuzzy Cognitive Maps.

When we analyze the unsupervised data we cannot say anything for certain, at several times we are forced to face the indeterminacy of facts; so the only powerful tool which helps us to understand and apply the concept of indeterminacy in the analysis of data is the notion of neutrosophy.

We have used in the place of fuzzy theory the concept of neutrosophy.

Here (in neutrosophy) we use the fact that between any two concepts/ nodes the existing relation may be an indeterminate (as) in reality, however as the notion of fuzzy cognitive maps do not help us to study indeterminacy in the analysis of the unsupervised data.

1. FCMs measure the existence of causal relation between two concepts and if no relation exists it is denoted by 0.

2. NCMs measure not only the existence of causal relation between concepts or the absence of causal relations between two concepts but also gives representation to the indeterminacy of relations between any two concepts.

3. We cannot apply NCMs for all unsupervised data. NCMs will have meaning only when relation between at least two concepts C_i and C_j are indeterminate.

Neutrosophic Cognitive Maps versus Fuzzy Cognitive Maps - cont.

4. The class of FCMs is strictly contained in the class of NCMs. (All NCMs can be made into FCMs by replacing I in the connection matrix by 0).

5. The directed graphs in case of NCMs are termed as neutrosophic graphs. i.e. in the graph we have at least two edges which are related by the dotted lines, means the edge between those two vertices is an indeterminate.

6. All connection matrices of the NCM are neutrosophic matrices i.e. they have in addition to the entries 0, 1, −1, the symbol I.

7. The resultant vectors i.e. the hidden pattern resulting in a fixed point or a limit cycle of a NCM can also be a neutrosophic vector; i.e. signifying the state of certain conceptual nodes of the system to be an indeterminate i.e. it is not off i.e. '0' not on i.e.'1' and indeterminate relation is signified by I.

8. Because NCMs measure the indeterminate, the expert of the model can give due careful representation while implementing the results of the model.

9. In case of simple FCMs, we have the number of instantaneous state vectors to be the same as the number of resultant vectors but in case of NCMs we see the number of instantaneous state vectors is from the set {0, 1} where as the resultant vectors are from the bigger set {0, 1, I}. This is also one of the major differences between NCMs and FCMs.

Suggested Problems.

1. Develop an algorithm for the FRM with m concepts in the domain space and n concepts in the range space to find the limit cycle, fixed point of the dynamical system when m and n are large.

2. Illustrate by a real world problem (i.e. real data used from any source) that FRMs serves better when concepts / nodes of the data can be divided into disjoint classes than using the FCMs.

3. Study the political situation in your hometown using

   i. FRMs,

   ii. FCMs.

Justify from your study which technique is better in this case.

5. Build an algorithm to find a pairwise linked FRMs. Hence or otherwise build an algorithm to find the n-linked FRMs and the hidden connection matrix.

6. Using the method of r-linked FRMs in a real world problem, show the hidden matrix is really a very difficult relation to be got as a direct opinion.

Suggested Problems – cont.

6. Consider the child labor problem. Now take 4 spaces (disjoint of course) as

G – government policies,

P – Public opinion,

C – Child labourers,

E – Educationalists (Teachers/ Heads of the School/ Educational Institutions etc.).

Now all the four spaces form disjoint notions / concepts. Form a 3 – linked FRM and study it, using data or opinions from experts.

7. It is said that the strength of the result depends on the larger number of experts. Prove or disprove it in case of FRMs using a real model.

8. Construct an example of a real model in which FRMs cannot be used and only FCMs can have a role to play.

9. In modeling the prediction of stocks and shares which model is appropriate FCM or NCM? Justify your claim.

10. Give a model in the real world problem to illustrate working of the linked FRMs.

Suggested Problems – cont.

11. Write an algorithm in Java or C++ to

    i. work with an n-linked NRM

    ii. work with an m-linked FRM.

12. Can a program be constructed to compare a NRM with FRM once the data is provided? Justify your claim.

13. Write a program to implement NCMs. (Hint: Use the program given for FCMs and modify it by including the indeterminacy 'I')

14. What can we apply for the death wish of the terminally ill [say, cancer] patients i. NRMs? ii. 2-linked NRMs? Which will be a better model? Justify your claim with real world data.

15. Compare using a real world data by applying FCMs and then NCMs. Which is better for this data? Justify your claim concretely.

16. Prove using data from any plant the modeling of supervisory systems using NCMs is better than FCMs.

17. Define different types of Balance degrees in case of neutrosophic graphs and illustrate them with examples.

Suggested Problems – cont.

18. Obtain some nice properties about balanced degree in neutrosophic digraphs. (Recall: A neutrosophic digraph D consists of a finite set V of points and a collection of ordered pairs of distinct points. Any such pair (u, ν) is called an arc or directed line or an indeterminacy (i.e. we are not certain whether they can be connected by an arc or by a directed line) and will usually be denoted by uv). In the definition of outdegree of a point υ of a neutrosophic digraph is the number of points adjacent from it and it includes also the dotted lines, which measure the indeterminacy, and in case of indegree it is the number adjacent to it (certainly all indeterminate dotted lines are taken) .

19. Construct a NCModeler (a software tool analogous to FCModeler) in creating metabolic and regulatory network models using NCMs. Hence or otherwise using a real world problem in a metabolic network prove NCMs give results closer to truth than FCMs, when the data under study involves a lot of indeterminacy.

29. Prove NCMs with circles may have very complicated hidden patterns. Hence or otherwise prove circles enable the feedback mechanism in NCM inference process to have important consequences in many real world applications.