Externalizing Tacit Knowledge to Discern Unhealthy Nuclear Intentions of Nation States

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Abstract

One of the enduring challenges in international relations with far-reaching consequences is discerning unhealthy nuclear intentions of nation states. Explicit Strategic Intelligence information available on such issues are in many cases vague, incomplete, sketchy or fragmented, rendering the process of discerning intentions reliant on tacit knowledge of experts in discerning intentions. The process of externalizing knowledge from Tacit to Explicit forms is one of the active areas of contemporary knowledge engineering research. This paper proposes a method based on Neutrosophic Cognitive Maps to objectively externalize the tacit knowledge of experts in such contexts to support better policy decision making. In order to demonstrate the methodology, the case of Iran's nuclear intentions is discussed with hypothetical expert opinion numbers.

1. Introduction

"The discovery of nuclear chain reactions need not bring about the destruction of mankind, any more than did the discovery of matches. We only must do everything in our power to safeguard against its abuse." *–Albert Einstein*

Conventional methods of analyzing intelligence information sometimes lead to controversial conclusions about the intentions of state nuclear programmes. The dilemma faced by strategic policy makers regarding the nuclear intentions of Iran is a case in point. While a section of the US Government asserted Iran was into developing nuclear weaponry, a National Intelligence Estimate published by the US National Intelligence Council (NIC) released in late 2007 concluded that Iran "most likely suspended its nuclear arms program in fall 2003 and that it's unlikely that Tehran is currently developing nuclear weapons"[1]. This resulted in a political controversy of sorts and challenged the basis of International Relations exercises where multi-lateral incentive/deterrent packages were being worked out for Iran. The question of whether the nuclear intentions of Iran are healthy or not continue to occupy the discourse and work of most policy decision-makers in the field of international relations.

Current method of formally discerning nuclear intentions of states (including in the case of Iran) involves environmental sampling, export/import monitoring, satellite imagery and other new technologies, extensive onsite investigations. A variety of intelligence information is processed in order to discern nuclear intentions, prominent among them being the IAEA country safeguards related findings. In general the IAEA uses three broad categories of information sources: information provided by the states, information derived from in-field verification activities and information obtained from other sources. These other sources include a variety of nuclear data-bases including nuclear illicit trafficking database, Open source information including information generally available from external sources, such as scientific literature, official information, information issued by public organizations, commercial companies and the news media, and commercial satellite imagery [2]. Arguably in the case of Iran, the same repository of IAEA and non-IAEA information was available to both the US Government and the NIC. How then did the inferences about nuclear intentions of Iran happen to be so controversial? On what basis then, should policy decision makers should take key decisions such as incentive packages and deterrence measures? This leads one to search for additional and newer methods of intelligence information processing in order to improve objectivity of inputs to policy decision making.

A closer examination of the information sources cited above indicate that all of them are explicit

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knowledge-based. Such information has the following characteristics

i) Information is not complete – it is on occasions vague, incomplete, sketchy or fragmented

ii) Except for technical indicators, most of the other linguistic information is processed in a discourse format. Methods of eliciting and representing expert opinion are predominantly discourse based question/answer/discussion formats. This discourse format of information processing provides a possibility for subjectivity and bias especially as regards the expert estimation of causalities leading to the suspicions of nuclear intentions.

iii) There are as yet no (known) approaches available to elicit, represent and utilize tacit knowledge which intelligence experts apply in processing causalities inherent in the discourses in reaching the final conclusion about the nuclear intentions.

In order to overcome the above lacunae, this paper proposes a method based on Neutrosophic Cognitive Maps (NCM) as an objective mechanism for eliciting, representing and using (externalizing) expert tacit knowledge in discerning nuclear intentions. The NCM methodology is preferred over Fuzzy Cognitive Maps (FCM) mainly because NCM facilitates computation of indeterminate cause-effect relationships which FCM does not permit.

Section 2 provides a brief background of Tacit knowledge. Section 3 gives the key features and methodological basis for generic NCMs. Section 4 provides a background of the Iran nuclear intentions case including information obtained from NIE report on Iran. The externalization of expert tacit knowledge through NCMs is explained and demonstrated in Section 5 and Section 6 summarises the results and Section 7 provides the conclusions.

2. Tacit Knowledge – A brief background

Pioneering work on tacit Knowledge was done by Michael Polanyi. His description of what constitutes tacit knowledge is "knowing a thing by relying on our awareness of it for the purpose of attending to an entity to which it contributes"[3]. However Nonaka [4] provides a more working level definition, "Tacit knowledge consists partly of technical skills—the kind of informal, hard-to- pin-down skills captured in the term "know-how"… At the same time, tacit knowledge has an important cognitive dimension. It consists of mental models, beliefs and perspectives so ingrained that we take them for granted, and therefore cannot easily articulate them"…It is this cognitive dimension of tacit knowledge that this paper will address. Further, Nonaka models knowledge transfer as a spiral process. Start with a 2x2 matrix, in which existing knowledge can be in either form - tacit or explicit - and the objective of knowledge transfer can be to convey either tacit or explicit knowledge. Each mode of transfer operates differently as shown in Figure 1.

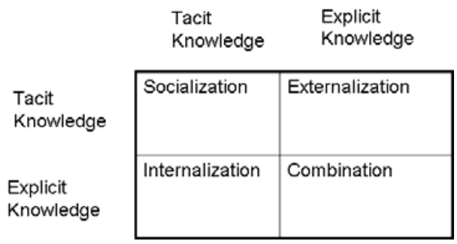

Figure 1: Nonaka's Four Modes of Knowledge Conversion

This paper will deal predominantly with "Externalization" which is the process for making tacit knowledge explicit. While different approaches exist in contemporary literature for externalizing tacit knowledge, this paper adopts an approach of causality based cognitive mapping, the details of which are discussed below.

3. Using Neutrosophic Cognitive Maps to represent tacit knowledge

First a brief background about cognitive maps in general is discussed followed by key features of Neutrosophic Cognitive Mapping.

3.1 Representing causalities with cognitive maps

A Cognitive Map (CM) is a graphical mental model that externalizes as a person understands, believes and organizes a subject of analysis. The design of the CM is fulfilled by interviews, documental forms, structured methods and the grid technique. A simulation process estimates causal behavior and outcomes. Thus, a set of initial values for the concepts' states are estimated and assigned to the concepts of the CM. Afterwards, it begins a cycle that is represented by discrete increments of time that gradually transform the values attached to the concepts' states. During iterations (t_j), causal effects are triggered according to the topology of the CM. As a result, new values for the concepts' states are outcome. These values represent a pattern that corresponds to a point in a search space $m_1*m_2*..*m_n$ dimensional. Where n is the number of concepts, and m_i the number of instances values for the concept i. The simulation breaks down when the process arrives at a stable situation, a pattern of values or a chaotic attractor. This means, that the simulation seeks convergence regions for the concepts. These regions represent stable situations where do not occur any more changes in the pattern. Otherwise, the simulation could meet chaotic attractors, which are regions where it is not possible to find out fixed patterns [5]

Applying Fuzzy logic onto CM, the method of Fuzzy Cognitive Maps (FCM) proposed by Kosko have found widespread application in a variety of fields ranging from disease diagnosis to intelligent intrusion detection systems [6].

3.2 Neutrosophic Cognitive Maps

A recent advance in the field of cognitive maps is Neutrosophic Cognitive Maps. This is based on neutrosophic logic created by Florentine Smarandache [7], which is an extension / combination of the fuzzy logic in which indeterminacy is included. 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. A key difference between Fuzzy Cognitive Maps (FCM) and Neutrosophic Cognitive maps is that Neutrosophic maps permit the relationship of "indeterminacy" between nodes which is not possible to perform in a FCM. Given the "black box" nature of tacit knowledge these indeterminate relationships are necessary for further exploring and research to be input into decision making.

Some of the essentials pertaining to NCM are listed below [8]:

i) 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_iC_j, $e_{ij} \in \{-1, 0, 1, I\}$. e_{ij} denotes the strength of causality. $e_{ij} = 0$ 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.

ii) Let $C_1, C_2, \ldots C_n$ be n nodes of the NCM. Let $A = (a_1, a_2, \ldots a_n)$ where a_i belongs to {0,1,I}. A is called the instantaneous state neutrosophic vector and it denotes the on-off-indeterminate state position of the node at an instant.

$a_i=0$ if a_i is off (no effect)
$a_i=1$ if a_i is on (has effect)
$a_i=I$ if a_i is indeterminate (effect cannot be determined)
for i=1,2,…n

iii) If the equilibrium state of a dynamical system is a unique state vector, then it is called a "fixed point". If the NCM settles with a neutrosophic state vector repeating in the form $A_1 \rightarrow A_2 \rightarrow \ldots \rightarrow A_i \rightarrow A_1$, then this equilibrium is called a limit cycle of the NCM.

iv) Let $C_1, C_2, \ldots, C_n$ be the nodes of an NCM, with feedback. Let E be the associated adjacency matrix. The "hidden pattern" is found as follows: When C_1 is switched on, an input is given as the vector $A_1 = (1, 0, 0, \ldots, 0)$ and the data passes through the neutrosophic matrix N(E). This is done by multiplying A_1 by the matrix N(E).

Let $A_1N(E) = (a_1, a_2, \ldots, a_n)$ with the threshold operation that is by replacing a_i by 1 if $a_i > k$ and a_i by 0 if $a_i < k$ (k – a suitable positive integer) and a_i by I if a_i is not an integer. The resulting concept is updated and the concept C_1 is included in the updated vector by making the first coordinate as 1 in the resulting vector. Suppose $A_1N(E) \rightarrow A_2$ then consider $A_2N(E)$ and repeat the same procedure. This procedure is repeated till a "limit cycle" or a "fixed point" is obtained. (→ stands for vector thresholding and updation).

4. Using Neutrosophic Cognitive Maps to discern nuclear intentions –The case of Iran

4.1 Iran – A brief nuclear history

Iran's nuclear program began in the Shah's era, 50 years ago including a plan to build 20+ nuclear power reactors. Two power reactors in Bushehr, on the coast of the Persian Gulf, were started but remained unfinished when they were bombed and damaged by the Iraqis during the Iran-Iraq war. Iran ratified the Nuclear Nonproliferation Treaty in 1970, and since February 1992 has allowed the IAEA to inspect any of its nuclear facilities. Prior to 2003 no IAEA inspections had revealed Tehran's violations of the NPT. [9] However IAEA inspections since 2003 have revealed two decades' worth of undeclared nuclear activities in Iran, including uranium enrichment and plutonium separation efforts. Iran agreed in 2003 to suspend sensitive activities in negotiations with Germany, France, and the UK (EU-3), which broke down in August 2005. On September 24, 2005, the IAEA Board of Governors found Iran to be in noncompliance with its Nuclear Nonproliferation Treaty (NPT) safeguards agreement and reported Iran's case to the U.N. Security Council in February

2006 [10]. Since then the world is anxious of any escalation in tensions between the USA and rest of the world with Iran and assessing nuclear intentions of Iran has been of paramount importance in the sphere of international relations. These tensions are also regarded as one of the key drivers of the prevailing extraordinary crude prices in international markets.

Meanwhile a National Intelligence Estimate (NIE) of National Intelligence Council (NIC) USA concluded "We judge with high confidence that in fall 2003, Tehran halted its nuclear weapons. We assess with moderate confidence Tehran had not restarted its nuclear weapons program as of mid-2007, but we do not know whether it currently intends to develop nuclear weapons…We continue to assess with moderate-to-high confidence that Iran does not currently have a nuclear weapon."[11]. This report created considerable controversies as it was viewed as being in contradiction with the prevailing US government views at that time. As the NIE could be expected to have more or less the same information that the US govt. had access to, one is curious to know how different conclusions could be reached by different agencies with the same or similar underlying information. This calls for further examination of the NIE report from an information processing perspective.

4.2 Intelligence Information processing and "Estimative language"

The NIE report as referred to above had interesting explanations as to the "estimative language" used in the report. NIE claimed:

i) "We use phrases such as *we judge*, *we assess*, and *we estimate*—and probabilistic terms such as probably and likely—to convey analytical assessments and judgments. Such statements are not facts, proof, or knowledge."
ii) "These assessments and judgments generally are based on collected information, which often is incomplete or fragmentary."
iii) "Some assessments are built on previous judgments. In all cases, assessments and judgments are not intended to imply that we have "proof" that shows something to be a fact or that definitively links two items or issues."

The above notings on "estimative language" are used below to provide key directions on the problem construction formalism.

4.3 Iran – Nuclear Intention Problem Construction

On examining the nature of the information processing issues, it is clear that

i) Information has been acknowledged to be not complete
ii) The connective between two elements or issues may not rest on complete proofs and leaves possibilities open for indeterminacies in the causal relationships which have not been exclusively considered in the intelligence information processing.

In order to overcome the above lacunae, an intelligence expert analysis of the Iran case is presented below with hypothetical numbers using NCM (discussed in section 3.2) which is capable of handling indeterminate causal connectives. Identifying the concepts, the causal interconnectedness and assessing the strength of the causalities are the key tacit knowledge elements of experts that is sought to be formally externalized using the NCM.

5. Using Neutrosophic Cognitive Maps to represent the Iran Nuclear intention problem

Three steps are involved in this method of tacit knowledge externalization:

i) Identifying pertinent concepts for the problem
ii) Constructing the NCM for the concepts using causality strengths
iii) Solving the NCM and interpreting results

5.1 Step 1: Identifying the pertinent concepts for the problem:

In identifying pertinent concepts for the problem, three key questions in the NIE report [11] have been considered

- What are Iran's intentions toward developing nuclear weapons?
- What domestic factors affect Iran's decision-making on whether to develop nuclear weapons?
- What external factors affect Iran's decision-making on whether to develop nuclear weapons

Given the real life Iran nuclear intentions case discussed in detail so far, from hereon the discussion will be based on hypothetical concepts and causal relationships provided to demonstrate the NCM externalization methodology with Iran as a case study. Table 1 presents a hypothetical set of concepts elicited from an expert. (Typically the same process applies for compiling opinions of multiple experts on the same situation since the underlying NCMs can be additively combined. However a discussion on multiple expert opinion compilation is currently not considered in this paper for purposes of space constraints).

Table 1 Concept elicited from Expert opinion obtained in discourse format

Concept No	Concept
C_1	Iran's move towards developing nuclear weaponry
C_2	Abundance of energy resources such as oil/Natural gas
C_3	Regional power balance needs
C_4	Field intelligence inputs-centrifuges etc.
C_5	Internal prestige – Need to get admitted in world order
C_6	Fuel Supply Assurance for nuclear power
C_7	State's level of military capability
C_8	Nature of nuclear research conducted by its nationals internally and abroad

5.2 Constructing NCM for the concepts

A NCM as shown in Figure 2 is constructed taking into account the concepts identified by the expert in Table 1 and his opinion on causal strengths.

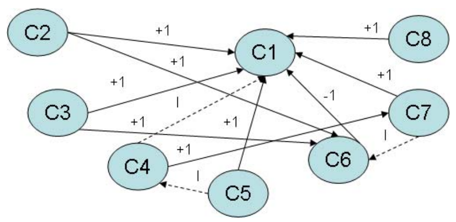

Figure 2: Neutrosophic Cognitive Map for representing expert tacit knowledge

The expert considers c_i, i=1,2,…8 as relevant concepts to determine whether a state has unhealthy nuclear intentions. As already discussed in Section 3.2, the strengths of the causality as opined by the expert are depicted in the adjacency matrix. The concepts where the expert is unable to either confirm or reject causality is marked as "I" (Indeterminate). These indeterminate elements are black boxes which the expert is not able to explicitly assign a causal strength based on proofs but nevertheless tacitly feels that there may be a causality involved.

The Adjacency matrix N(E) is now defined as follow.

Applying the state vector A_1=(1 0 0 0 0 0 0 0 0) on the state of Node C_1, we obtain the effect of A_1 on N(E) as

A_1N(E) = (0 1 1 I 1 -1 1 1) → (1 1 1 I 1 0 1 1) = A_2

A_2N(E) = (5+I 1 1 2I+1 1+I 1+I 1+I 1) → (1 1 1 1 1 1 1 1) = A_3

N(E) =

	C1	C2	C3	C4	C5	C6	C7	C8
C1	0	1	1	I	1	-1	1	1
C2	1	0	0	0	0	1	0	0
C3	1	0	0	0	0	1	0	0
C4	I	0	0	0	I	0	1	0
C5	1	0	0	I	0	0	0	0
C6	-1	1	1	0	0	0	I	0
C7	1	0	0	1	0	I	0	0
C8	1	0	0	0	0	0	0	0

A_3N(E) = (4+I 2 2 1+2I 1+I 1+I 2+I 1) → (1 1 1 1 1 1 1 1) = A_4

A_3=A_4: Fixed point reached.

Where the symbol → stands for vector thresholding and updation is based on k=1 as per rules specified in section 3.2(iv).

6. Results and Discussion:

Based on the resultant Vector (1 1 1 1 1 1 1 1) , it can now be unambiguously concluded that there exists strong ground for a move towards development of nuclear weaponry by Iran. Though initial causal Indeterminates due to information deficiencies were present for the expert in the explicit domain, subsequent representation through a NCM and solving has lead to the unambiguous conclusion. (However it has to be once again noted here that all edge weights and concepts as of above are purely hypothetical and do not imply reality in the Iran case. These numbers have been presented merely for purposes of illustration.)

Some of the advantages of the above NCM based method are

i) Complex non-linear representation and computation of expert perceptions/opinion of the problem and concepts involved.
ii) Flexibility to include multi-disciplinary inputs.
iii) No imposed pre-designed analyst influenced criteria for eliciting expert opinion thereby facilitating emergence of hitherto unidentified tacit knowledge elements.
iv) Inclusion of indeterminate causalities which is particularly necessary given the incomplete nature of intelligence information.

There is scope for further research on the above solution construct especially with regard to expanding the scope and integrating the above externalization methodology with the other three modes of Nonaka's Knowledge transfer method. This would add more comprehensiveness to intelligence information processing in the context of discerning nuclear intensions.

7. Conclusion

This paper discussed the methodology of using a Neutrosophic Cognitive Map to externalize tacit knowledge of experts in discerning nuclear intentions. The approach was demonstrated using a case study of discerning Iran's nuclear intentions. Incomplete/indeterminate information and complexities are problems facing policy decision makers around the world in discerning nuclear intentions of suspect states. The externalization methodology as discussed in this paper seeks to address this challenge by allowing a methodological rigor in objectively discerning such intentions using a non-linear approach in combination with the ability to integrate "indeterminacy" in intelligence information processing.

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