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SHORT COMMUNICATION

Expert Systems for Computerised Wargames

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ABSTRACT

Computerised wargames have emerged as an important tool to train the field commanders in a cost-effective manner, because of its ability to incorporate all the mechanics and vagaries of warfare, and at the same time reduce the cost and complexity of stage-managing such training. However, while trying to convert tactical combat rules into a computerised system within the rigid limitations of software semantics, the very essence and dynamics of the phenomenon of warfare as manifested in field are likely to be lost. Such loss of critical aspects could make the output of the system unrealistic, which in turn may compromise its training value. Besides this, to develop a system based on software directly translated from conventional rules, one has to clearly define the phenomenon of warfare at extremely high resolution and accuracy. The process of defining a highly uncertain phenomenon like warfare at such high resolutions and thereafter, framing extensive rules for all the possibilities can make the system extremely complex and therefore unmanageable in many ways. This paper attempts to simplify this problem by proposing a simpler and better technique using an algorithm based on fuzzy logic. Its basic advantage over conventional systems is that it has the inherent potential to handle even highly complex phenomenon like warfare in a fundamentally simple manner. Such potential makes it capable of handling higher level of details and still contain the complexity of the software within manageable limits. Additional details would also make the system more accurate and realistic. Introduction of flexible models, like the proposed one, would definitely help improve the realism of the outcome generated in computerised wargames, thereby enhancing their training value.

Keywords: Expert systems, computerised wargames, fuzzy logic, decision support systems, decision-making, training

1. INTRODUCTION

Thought oriented fine elements, such as intelligence, knowledge, experience and tactical skills, along with action-oriented elements, which include leadership, courage, motivation, and morale have turned warfare into a complex fine art. This art can only be learnt and honed up the hard way through continuous training. Computerised wargames have emerged as an important tool to carryout such training in the least expensive manner with its ability to include most of the complexities of warfare, and at the same time reduce the cost and efforts of stage managing the same.

2. LIMITATIONS OF PRESENT WARGAME SYSTEMS

Computer-based systems available today demand a great deal of objectivity. When one tries to develop a computer-based system, one experiences the necessity to translate all aspects into clear well-defined certainties. However, most often than not, tactical visualisations and aspects of warfare cannot be precisely divided into such crisp and well-defined formats. An example of the inadequacy of the present system can be highlighted by examining the difficulty faced in translating generic tactical semantics like adequate cover available.

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In this case, how one can determine the percentage of cover being adequate? Can one say 70 per cent of cover is adequate? Does it mean that 69 per cent cover is inadequate? Yet another example could be the determination of battle-worthiness of a unit based on casualties suffered. If one were to fix 30 per cent casualties suffered as the degree determining battle-worthiness of a unit, does it mean that 30 per cent being unworthy and just 29 per cent being fully battle worthy?

People are also faced with similar dilemma when they deal with intangible factors like leadership, morale, etc. The main reason for the inadequacies confronted when translating real-life situations to crisp certainties, required for a computer program, is due to the fact that uncertainties and imprecision are inherent in all real-life situations. It is well known that much of the information received from battlefront and made available to a military commander, based on which he is expected to make decisions are imprecise in nature. Besides this, tactical doctrines themselves contain many similar uncertainties and grey areas. Unfortunately, when similar knowledge base needs to be translated into a software for computerised wargames, the system permits very little tolerance for any such inherent uncertainties or imprecision. Such difficulties have been imposing severe limitations in our efforts towards development of realistic automated decision support systems. Of late, it is being increasingly realised that translation of imprecision or vagueness that is characteristic to natural language or tactical semantics into a computer-based system need not necessarily imply loss of accuracy or meaningfulness. Expert systems based on new types of mathematical techniques are being developed, which have the inherent capability to deal with both precise and imprecise information together. One such system is based on fuzzy logic algorithms.

3. FUZZY LOGIC FOR COMPUTERISED WARGAMES

One of the problems faced, while creating a wargame model, is to come up with a realistic means for the prediction or determination of an event in the course of an ongoing operation, based on incomplete, and sometimes vague set of information available at that point of time. To obtain realistic results, one would like to know not only how to utilise the available information, but also how to deal with uncertainty and imprecision that is inherent in the same.

3.1 Combat Rules

Tactical acumen developed by a field commander originate from the cumulative background of knowledge, experience as well as intuition that he acquires during the course of his profession. When one builds a model for computerised wargames, one would like to assume that this background is being translated into the automated system by as close a degree as possible. However, such translation is extremely difficult to achieve since the computer programmer, who besides being not only unfamiliar with the subtle nuances of military tactics does it within the severe limitations of the software semantics. Such a situation also puts limitations in the scope of expression while framing the combat rules. With the introduction of fuzzy logic system of framing the rules, the expert committee can be given the freedom of expression in more generic but tactically correct terms in simple english language. Such a system would be able to accept most of the regular tactical terminology given by the expert committee in a better way without compromising with their actual meaning.

3.2 Conflict Resolution

When a computerised wargame model generates realistic outcomes, it would definitely build up user confidence in the very idea of such wargaming. A realistic model would also go a long way in honing up the analytical skills of the field commanders and therefore immensely increase its training value as well as other associated positive spin-offs. Conflict resolution, which entails selection of one out of the multitude of possible outcomes by the system, is another important aspect, which can be modelled through a suitable fuzzy logic algorithm.

3.3 Simplified Decision Support Algorithm

Even though a computer-based system can simultaneously take on any number of factors required to be considered, while arriving at an outcome, here for the sake of simplicity for explanation, let an example of a simple case of selection be taken using an elementary fuzzy logic algorithm. Let it be assumed that the situation is a simultaneous attack being launched against four defensive nodes of the Red Land by the Blue Land Forces. The computer has to identify the node, which is likely to get reduced first, based on which further operations are to progress. Even though there is no limit to the number of factors that could be considered by a fast computer, here for convenience only six factors are considered as given below:

(a) All those factors that favour the likely reduction of a node can be called goal factors. The four goal factors could be

- Goal factor G_1 – the distance from the line of communication
- Goal factors G_2 – the strength and disposition
- Goal factors G_3 – the state of enemy defences
- Goal factors G_4 – the importance of the node from tactical point of view

(b) All those factors, which restrain the likely reduction of a node, can be called constraint factors. The two constraint factors could be

- Constraint factors C_5 – the ground.
- Constraint factors C_6 – the number of fire units available for reduction of a node.

3.4 Fuzzification Graphs

The fuzzyfication graphs have to be made in consultation with the expert committee since this actually translates the relationship between the input variables and the membership values, which would be used further in framing the rules (Figs 1-3)

3.5 Fuzzy Combat Rules

The membership values derived out of the fuzzification graphs would be used for framing the fuzzy combat rules. The fuzzy combat rules would therefore be a direct translation of the tactical combat rules framed by experts from the Armed Forces into the fuzzy form. The domain names in

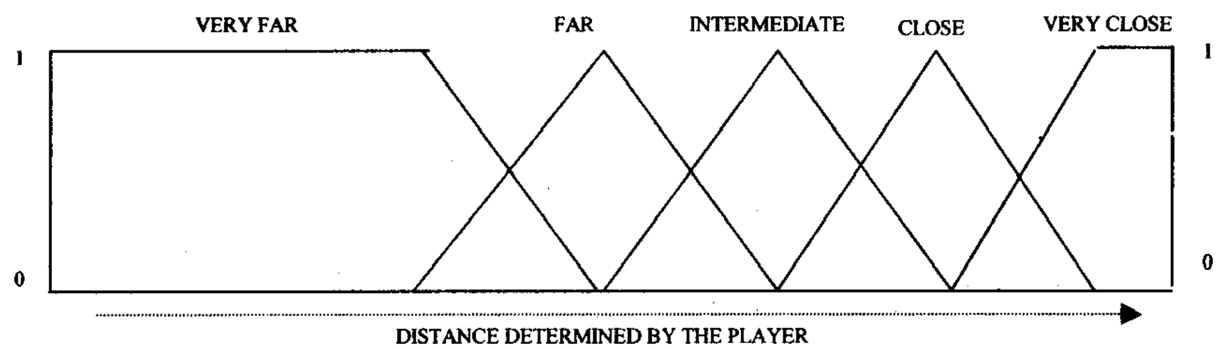

Figure 1. Fuzzification graph for distance from the line of communication

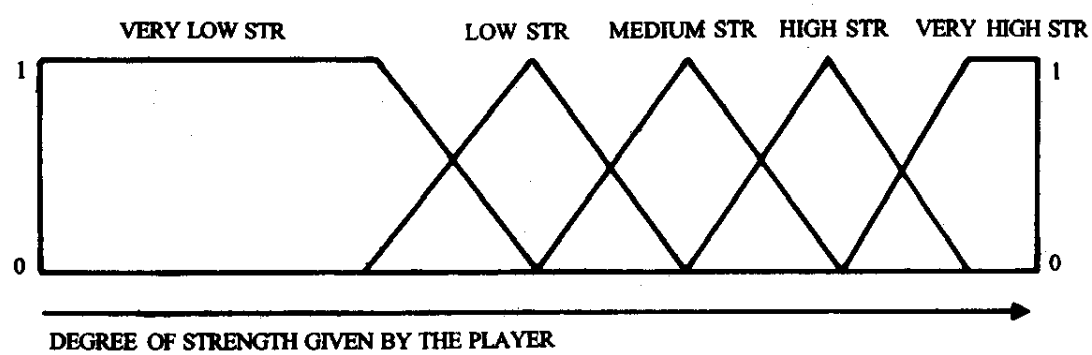

Figure 2. Fuzzification graph for strength and disposition

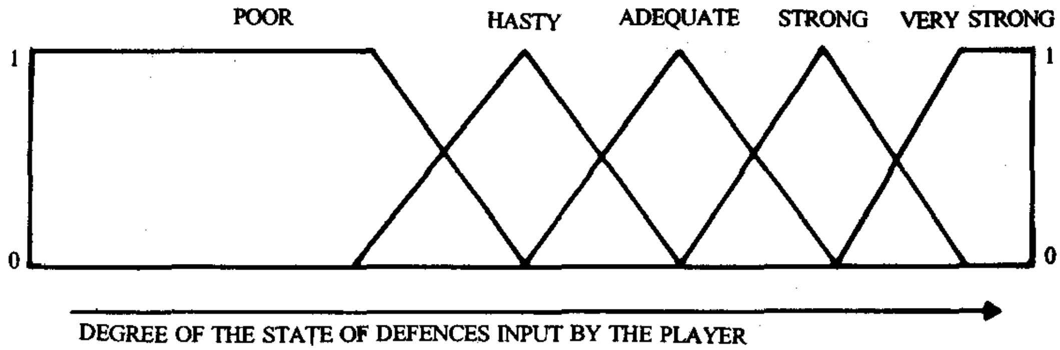

Figure 3. Fuzzification graph for state of enemy defences

the fuzzyfication graphs would be as close as possible to the terminology used in the tactical combat rules since such terminology has already been incorporated earlier in the fuzzification graphs for this purpose. The rules would inherently define all the desirable combination of gain and constraint membership functions that favour conditions conducive to the attack/reduction of a node. Two examples of the fuzzy combat rules are:

G_1(Close) AND G_2(High Str) AND G_3(Hasty) AND-------------- = a_1

Similarly

G_1(Far) AND G_2(Low Str) AND G_3(Strong) AND-------------- = a_2

The term G_1 (Close) refers to the membership value obtained from the fuzzification graph of distance from the node for a particular input value in the fuzzy domain range of close in the graph. The output values given by the rules eg, a_1 is to be arrived at using the fuzzy operator AND. The AND operation could be done by any suitable fuzzy aggregation techniques like minimisation. The output given by the rules are put in the form of an output set like R_{x1} = {a_1 a_2 a_3 a_4 a_5---}. If the four nodes of the Red Land were listed as x_1, x_2, x_3 and x_4, the rule sets would be arrived at for x_1, x_2, x_3 each possible outcome as

R_{x1} = {a_1 a_2 a_3 a_4 a_5----} = Rule output set derived from the input factors pertaining to node 1

R_{x2} = {b_1 b_2 b_3 b_4 b_5----} = Rule output set derived from the input factors pertaining to node 2

R_{x3} = {c_1 c_2 c_3 c_4 c_5----} = Rule output set derived from the input factors pertaining to node 3

R_{x4} = {d_1 d_2 d_3 d_4 d_5----} = Rule output set derived from the input factors pertaining to node 4

3.6 Fuzzy Rule Sets

To simplify the explanation, it has been assumed that the rule sets have already been arrived at as explained above with each set consisting of only six rules. For the ease of further computations, the values available within the rule sets have been regrouped into the following sets:

R_{o1} = {a_1 b_1 c_1 d_1} = {0.8 0.95 0.3 0.13} = The output of the first fuzzy combat rule pertaining to all the nodes

R_{o2} = {a_2 b_2 c_2 d_2} = {0.7 0.4 0.3 0.4} = The output of the second fuzzy combat rule pertaining to all the nodes

R_{o3} = {a_3 b_3 c_3 d_3} = {0.3 0.7 0.5 0.2}= The output of the third fuzzy combat rule pertaining to all the nodes

R_{o4} = {a_4 b_4 c_4 d_4} = {0.9 0.4 0.6 0.15} = The output of the fourth fuzzy combat rule pertaining to all the nodes

R_{o5} = {a_5 b_5 c_5 d_5 }= {0.5 0.4 0.7 0.3} = The output of the fifth fuzzy combat rule pertaining to all the nodes

R_{o6} = $\{a_6\, b_6\, c_6\, d_6\} = \{0.7 \quad 0.9 \quad 0.4 \quad 0.5\}$= The output of the sixth fuzzy combat rule pertaining to all the nodes

3.7 Weightage

Since all the above combat rules may have varying degrees of relevance towards the outcome, it is required to weigh them accordingly. Such weightings can always be done by the expert committee *ab-initio* while initiating the wargame based on the tactical situation depicted. The weightages could also be used to incorporate a learning mechanism onto the algorithm through multiple iterations based on past experiences to correct minor inconsistencies in the output. In such a mechanism, fine-tuning of the weightage would be carried out every time the output of the system tends to vary from that of the expected output. In the subject example, it is assumed that the rules have following weightage:

Weightage for $R_{o1} = w_1 = 0.5$

Weightage for $R_{o2} = w_2 = 1.5$

Weightage for $R_{o3} = w_3 = 0.6$

Weightage for $R_{o4} = w_4 = 2.2$

Weightage for $R_{o5} = w_5 = 0.4$

Weightage for $R_{o6} = w_6 = 0.8$

It has to be ensured that the sum of weightage is equal to the sum of the total number of rules. In this case 2.2 + 1.5 + 0.6 + 0.5 + 0.4 + 0.8 = 6 which is equal to the total number of rules being considered.

3.8 Optimisation Matrix

The model arrives at the optimum rule value (ORV) of a particular node for the progress of the wargame is:

$$\text{ORV} = \text{Max}\,[\text{Min}\{R_{o1}(x)^{w1}, R_{o2}(x)^{w2}, R_{o3}(x)^{w3}, R_{o4}(x)^{w4}, R_{o5}(x)^{w5}, R_{o6}(x)^{w6}\}]$$

To arrive at the result by min-max operation, the complete set can be put in a matrix form as

$$\text{ORV} = \text{Max} \begin{vmatrix} (0.8)^{0.5} & (0.95)^{0.5} & (0.3)^{0.5} & (0.2)^{0.5} \\ (0.7)^{1.5} & (0.4)^{1.5} & (0.3)^{1.5} & (0.9)^{1.5} \\ (0.3)^{0.6} & (0.7)^{0.6} & (0.5)^{0.6} & (0.2)^{0.6} \\ (0.9)^{2.2} & (0.4)^{2.2} & (0.6)^{2.2} & (0.15)^{2.2} \\ (0.5)^{0.4} & (0.4)^{0.4} & (0.7)^{0.4} & (0.3)^{0.4} \\ (0.7)^{0.8} & (0.9)^{0.8} & (0.4)^{0.8} & (0.5)^{0.8} \\ \downarrow & \downarrow & \downarrow & \downarrow \\ \text{Min} & \text{Min} & \text{Min} & \text{Min} \end{vmatrix}$$

$$\begin{aligned} \text{ORV} &= \text{Max}\ \{0.48 \quad 0.13 \quad 0.16 \quad 0.015\} \\ &= 0.48 \text{ which corresponds to } x_1 \end{aligned}$$

It can be observed that the node selected for reduction as per the system is the one assigned with x_1, i.e., the first node. The selection was made using the rules that defined the conditions that favour attack on a node. Similarly, a different set of rules that define the conditions that favour rejection of a node could also be used for selective rejection of three out of four nodes one by one. Such a system would also lead to the selection of a particular node for attack/reduction. Either or both methods could be used based on the accuracy of realism generated by them. Similar selection criteria can also be used to determine other output variables like casualty suffered, distance covered in advance or even the ultimate outcome of a battle itself.

4. CONCLUSION

Expert systems like that based on fuzzy logic have proven to be of great advantage especially in fields of day-to-day life. Definition of the phenomenon being modelled does not have sharp boundaries, but displays transition from one to another in a gradual manner. Crisp logic systems demand breakdown of such gradual transition into a definite well-defined structure with sharp boundaries, amenable for being processed by the computer. Such breakdown can make the phenomenon loose much of its original profile. To avoid this, the system has to be developed at very high resolutions, which could make it extremely complex. Fuzzy logic system offers a fundamentally simple way to handle such complex situations without making the system itself exceedingly complex. Employment of fuzzy logic algorithms would also ease out the present day incompatibility between the tactical and software semantics while developing realistic models for computerised wargames.

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Major Mohan Vizhakat, SM, was commissioned to the Corps of Signals from Indian Military Academy, Dehradun, in 1983. He did BTech in Electronics and Telecommunications Engineering. During his service in the Army, he had been involved in conceptualisation, design, planning, implementation and operation of various types of static as well as mobile network-based automated communication systems at a variety of locations including cities, deserts, jungles and mountains around the country. Presently, he is posted to the Snow & Avalanche Study Establishment (SASE), Chandigarh. He has been intimately involved in installation of the network of automatic weather stations (AWS) around distant posts in the Siachen sector with corresponding satellite telemetry linkup directly with the R&D Centre, SASE. He is also involved in the development of an expert software model for online evaluation of data obtained from the AWS network, for the purpose of avalanche forecasting. He is also a member of the Institution of Electronics and Telecommunications Engineers.