CONNECTIONIST APPROACH FOR REPRESENTATION OF UNCERTAINTY IN KNOWLEDGE BASES

José Ramírez G., Irene Torres Hecker

PARADIGMA C.A.

Apartado 1087. Ciudad Guayana 8015

VENEZUELA

ABSTRACT

The intention of this work is to present an scheme for uncertainty representation in knowledge bases, based on two main aspects: the **relative importance** of evidences for reduction of uncertainty in conclusions and the **degree of belief** in each evidence, derived from its accuracy, perception method and subjectivism.

This work proposes a representation that expresses the relative importance of each evidence for the affirmance or negation of a conclusion, similar to the way it is done in a constraint satisfaction network. Also, the degree of belief -as we show- is naturally handled by this model.

In our proposal we consider a network with evidences as knowledge nodes formed by the following elements:

- A closed world (W)
- Defaults applicable (D)
- A threshold for the activation of such node (θ)

- A relative importance for the affirmance of a conclusion, similar to the weighted links of a connectionist model.(1)
- An inference engine that processes the nodes similar to a constraint satisfaction network.

THE CERTAINTY FACTORS

The use of certainty factors in the inference process on a Knowledge Base and their composition for a final conclusion are based on the criterion of increasing or decreasing their value according to the presence of certain evidences which contribute to affirm or deny a particular conclusion, inside a given alternative.

Though, if human behavior is to be modeled, there might be cases in which the presence or absence of evidences is not enough for someone to modify the previous certainty of a conclusion.

The certainty factors based upon probabilities will work adequately for cases which occur over a short period of time and considering a representative sample. For long term periods probabilities will change for statistical reasons and in consequence the certainty factors would be adjusted not necessarily reflecting reality.

There also will be present the problem of monotonic reasoning because the certainty factors already set won´t be updated with the inclusion of new evidences in the knowledge base. Similarly, context for which certainty factors based on probabilities have been set, may vary too.

On the other hand, evidence is always obtained through a perception process which involves some degree of error, derived from the media used for its acquisition (human or devices). This is not represented when using certainty factors.

Additionally, the absence of evidences is not taken into account for the calculation of the certainty of the final conclusion, and eventually this could reduce the uncertainty related to it.

The initial setting of the certainty factors value is arbitrarily done and corresponds to the suggestion made by experts participating in the development of the Knowledge Based System. Nevertheless, after the System delivery these values may be subjected to an automated updating approach, and commonly these approaches are based on the decrease of the value of the certainty factors associated with seldom-firing rules, and the increase of the value of those certainty factors corresponding to rules which are frequently fired.

Very likely, the described process will lead to a limited Knowledge Base, unable to answer to the expected variety of situations originally posed. There will be "forgotten" rules, that in case of being applied won't reach a conclusion because of their "weakness".

EXPERIENCE, DEGREE OF BELIEF, IMPORTANCE

When evidences for a given conclusion are perceived by human beings, there is a "degree of belief" which represents the confidence they have in the accuracy of the values obtained. In fact, this feature won't necessarily change with the recurrence of the evidence over time.

The degree of belief on a given evidence -as we mentioned before- arises from the recognized subjectivism and perception error involved in the process of acquiring it.

In order to set a conclusion it is possible either to strengthen it with several evidences or to reduce the uncertainty by considering the absence of other evidences as a determining factor.

This defines relations between evidences and evidences, evidences and conclusions, conclusions and conclusions. This relations sustain the consistency of the Knowledge Base and add weight to the decision.

Each evidence, individually taken, has its own contribution to the affirmance of the conclusion which would be referred to as the "importance" of the evidence.

The degree of belief of an evidence and its importance are independent factors, and are independently managed in the model proposed. The former could be seen as the parameter which determines the influence field of a particular element in its value space, making it acceptable even when not exactly what expected. From this point of view it would be adjustable, but that would be done in a not dynamic way.

The degree of belief is conceptually a very stable value which will be updated just in case of detecting that it was wrongly set, or due to changes in the methods of perception.

Both, the degree of belief on the values, and the importance conceded to evidences are mainly based on experience.

THE CONNECTIONIST MODEL

As a representation for dealing in a natural way with the evidences, their degree of belief and importance relative to a conclusion we propose the use of a connectionist model, as shown in figure 1.

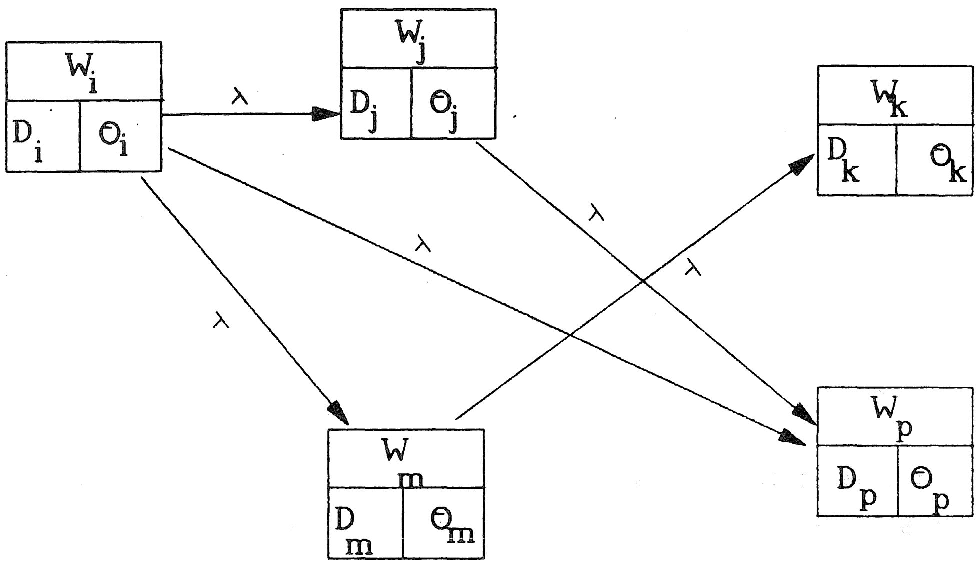


Fig.1 Connectionist model

each element of the network corresponds to a "Knowledge Node" (KN) formed by:

W

The closed World containing the rules related to the actual node (R), the facts (F) and the particular values (V).

D

The defaults applicable to determine the evidence in the node.

Θ

The threshold for the activation of the knowledge node output.

Λ_{ij}

The links between Knowledge Nodes, corresponding to the value of the importance of each evidence to each other or to conclusions.

So, the Structure of the Knowledge Base (KB) would be as follows:

$$KB = \{(KN_1, \Lambda_1), \ldots, (KN_n, \Lambda_n)\}$$

$$KN_i = (W_i, D_i, \Theta_i)$$

$$W = \{(r_1, \ldots, r_n), (f_1, \ldots, f_n), (v_1, \ldots, v_n)\}$$

$$D = \{(d_1, \ldots, d_n), (e_1, \ldots, e_n)\}$$

$$\Lambda = (\lambda, KN_{target})$$

The degree of belief on each value for the evidences of a Knowledge Node is originally set for all those values obtained through perception. Every possible evidence will be represented in the model. Taking advantage of the network structure, the correlation between the individual evidences will naturally occur.

THE INFERENCE

The inference process on the described model will take place similar to a constraint satisfaction network. The goal is to obtain the conclusion for which the greater number of more important evidences are established. The inference process consists of a set of non-probabilistic functions, as will be shown.

Considering three nodes: i,j,p, the inference engine process will determine the following values:

E_j

the evidence in the actual node, the value of a composition function of the evidences, defaults of the world and the world itself, defined as:

$$E_j = k(Net_{ij}, D_j, W_j)$$

where Net is the vector of incoming evidence, defined as:

$$Net_{jp} = \{E_j, S_{jp}\}$$

where S_{jp}

is the strength of the connection between nodes j and p defined as:

$$S_{jp} = h(A_j, \lambda_{jp})$$

where λ_{jp}

is the importance of $_{i..j}$

as evidence for p and A_j

is the activation function defined as

$$A_j = f(S_j, \theta_j)$$

where θ_j

is the threshold in the node and S_j

the strength of the evidence, is a function calculated on the degree of belief of the different values of the evidence and the strength of the connection thru which they came to the actual node. It is defined as:

$$S_j = g((\beta_1, \ldots, \beta_n)_j, S_{i,j})$$

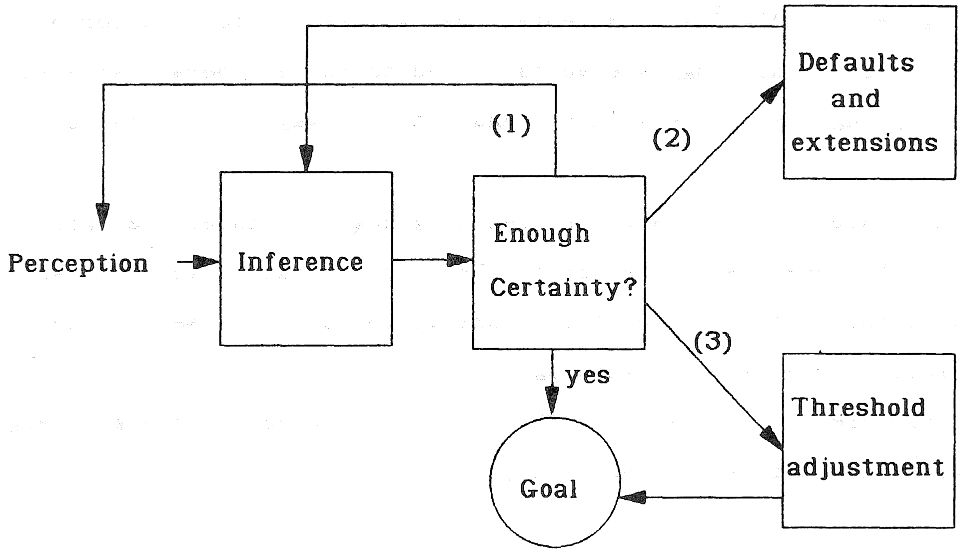
Where β_i

is the degree of belief of value i

In the connectionist models, particularly in the Ndimensional Coulomb Model, there are typically three strategies for conflict resolution: A conservative one in which a result will be accepted only if it has been set with a unique value whose certainty is greater than a given threshold. A moderate approach where some degree of ambiguity is accepted, being possible to look for other sources of knowledge (Defaults); and third, a liberal strategy, accepting a solution with no regard to the way it is obtained.

There are two main aspects defining how the inference process will be take place. The first one is the establishment of where will the conflict resolution take place, and the second one is properly the selected strategy for each conflict resolution point considered in the network. The inference process on the knowledge nodes not defined as decision points will be parallel.

According to what we just mentioned the inference process would be as shown in figure 2.



(1) Conservative approach
(2) Moderate approach
(3) liberal approach

Fig. 2 Inference process

The results of the calculation of the evidences would be a conclusion with its associated certainty. If the value of the certainty surpasses the value of acceptance -even in a conservative mode- the conclusion will be valid. But, if the value of the certainty is under the acceptance value there are several possible actions depending on the desired answer, at a decision point.

From a conservative point of view (1), a new data acquisition -perception- and total redoing of the inference process would be necessary.

In a moderate approach (2), new sources for completing the knowledge involved in the inference would be used. Specifically we propose the conduction of Commonsense Reasoning based on Defaults Theory. Commonsense is made up of positive evidence and absence of contradictory evidence. Normally there are more negative facts to be said about a particular conclusion - things against other conclusions, than things to positively affirm it. So, negative facts do are relevant information in a decision-making process. On the terms we just described, Defaults Theory seems to fit really well for the affirmance of facts when there is no reason for denying them, because of the consideration of the possible presence of contradictory facts.

A default value will be calculated and asserted for each evidence which couldn´t be set during inference.

Finally, when working in liberal mode (3), any conclusion at which the process could have arrived would be taken neglecting its certainty value.

So, there will always be present -in one way or another- the incidence of the missing evidences.

ADAPTATION AND LEARNING

The adaptation of the Knowledge Base is expected to be accomplished through different mechanisms. They will depend on the contribution of each inference process executed on it, which varies upon the strategy selected for conflict resolution in the decision points of the network.

In the case of moderate and liberal strategies, the defaults are used and proper extensions are generated as explained in (Eckmiller 1.987), these extensions are valid only in the session or context in which they are being used. The generation of extensions gives an adaptive behavior to the model. As mentioned before, in the liberal strategy thresholds are just reference values.

For an specific inference process, if a moderate or liberal conflict resolution strategy is to be used at any point, recurring to the revision of defaults and generation of extensions then the importance of the particular evidence being considered should be lessen to reflect that it wasn´t constructed as rigorously as possible when using the determined values.

The training of the model follows a multi-layer network approach; considering case studies presented to the model and confronting the output with the expected solution, calculating the error and propagating it back through the net, causing the adjustment of the thresholds and the importance factors. The cases are initially defined by the knowledge engineer and are updated with the unsolved situations presented to the model and the solutions given by experts.

In every decision point where a conservative conflict resolution approach will take place it would be necessary to have -talking in connectionist jargon- a supervised scheme of learning in which the system could be told about the adequacy or inadequacy of its answer.

If a particular answer was expected and not reached then the evidences participating in the inference should decrease their threshold value. But an evidence taken with less elements shouldn't be as important for the conclusion as if it were taken with all its elements determined through reliable sources.

If a particular conclusion was reached and the evidences participating in the process are consciously not considered enough to support that conclusion (there is no adequate correspondence between the expected and the real answer of the system), then the threshold values of all these evidences should be increased, and their importance may be decreased meaning that it's necessary the presence of other evidences to reach the conclusion.

CONCLUSIONS

1. The use of a connectionist model for structuring a Knowledge Base composed by Knowledge Nodes allows to represent elements such as evidences, their associated degree of belief and their importance relative to other evidences or conclusions. These parameters seem to offer a more reliable way for managing uncertainty than previously known approaches.

2. The inference process similar to that of a constraint satisfaction network and conducted based on the conflict resolution strategy adopted for the relevant decisions, allows to reduce the uncertainty inherent to conclusions of the System, by taking into account the missing evidences and the combined action of multiple evidences.

3. The proposed representation and inference method guarantee an updating mechanism based on the inclusion of new evidences through extensions to the Knowledge World.

4. Future work will be oriented toward an implementation in an object oriented environment. Also, more detailed treatment of the aspects related to learning and adaptation will be studied.

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