Schema Satisfaction Reasoning and Its Applications

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INTRODUCTION

Schemas have been widely used in the domain of psychology in general and cognitive psychology in particular, to indicate how certain configuration of chunks of information can participate in memorizing significant issues to be later used in life activities (Brewer & Nakamura, 1984; Gureckis & Goldstone, 2010; Gick & Holiok, 1983). Schemas are important since they have been shown to be influential as chunks of memory in various decision processes. Within this scope, schemas have been shown to achieve a high role in organizing information in short –term memory that is essential to solving a variety of problems (Chase & Simon, 1973). Schemas in the meantime have been shown to be influential in the graphical production of complex abstract imagerial entities such as diagrams (Obaidellah & Cheng, 2009). The important point with regard to schemas is that they may not necessarily approve each other mainly due to the fact that they are learned at different occasions, and process of consistency checking to assess them together, thus may not be easily achievable. Moreover, schemas are generally different from procedural (implicational) schemes for representing knowledge such as IF-THEN type rules mostly due to the point that no particular considerations exist with regard to concepts such as "condition" and "action" in their structures.

Taking the above points into account, it would be important to see how different schemas, which are not necessarily consistent with each other, can co-participate in the processes of reasoning essential to cognitive tasks. Let say, a format is necessary in this regard that can handle the probable non-monotonic-ness & inconsistency in a systematic way. Such a format can hardly be symbolic like the way conventional rule-based deductive reasoning functions, and instead a sub-symbolic format is required to implement reasoning under the activation of these schemas.

Although analogical reasoning in general, and case-based reasoning in particular, have been shown to make use of pre-experienced chunks of knowledge for inferring results in many domains (Gentner, 2003; Sowa & Majumder, 2003; Vosnladea & Ortony, 1989; Kolodner, 1992; Aamodt & Plaza, 1994), they may however face serious problems when the derived solution is expected to be a product of combining, composing or integrating the previous solutions stored in the cases similar to the current problem. This means that some inference rules would be needed that can take the responsibility of solution adaptation in some way.

Taking the above point into account a sub-symbolic architecture with connectionist nature can be a suitable alternative for taking care of the stored schemas in a connectionist manner. Within this context, provided that each schema can in the meantime include a certain class (of concept) as an identity, the justification patterns as well as the relations between the constituents of a schema, as well as the criteria essential to problem solving, can also be stored to perform this type of reasoning more reliably.

Hopfield Network (Bidirectional associative memory (BAM)) (Hopfield, 1982) has been shown to be a suitable choice for satisfying inputs' constraints through considering a suitable energy function for the entire network. Such a function is considered in a way that the total energy (stored in the network) can decrease in a gradual way, so that under certain circumstances, may converge into a minimal state with a stabilized activation charge for some of the nodes. Such nodes

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should then be regarded as the final decision expected from the network, e.g., identification, recognition, retrieval, optimization tasks, etc.

Taking the above discussion into account, one may come to the conclusion that the Hopfield Network has basically the potential to realize schema satisfaction in the way depicted above.

BACKGROUND

The point which is emphasized in this section is the role of constraint satisfaction networks in problem solving and optimization issues.

Facts, as conceptual entities gathered from different places on different occasions, are in different relations with each other. The ground for such relations is either the semantic relations between the related propositions, i.e. how far entities are semantically close or relevant to each other, or the pragmatic realities ruling over these conceptual entities as products of experience, i.e. how their ensemble may stand for a certain context as a certain class of concept with peculiar identity. When these conceptual entities come together to constitute a shared basis for inference purposes, the relations discussed above, would appear in a significant way. Let say, based on the status of a problem's inputs as the existing constraints, these relations are activated in such a manner that, out of the existing facts those, which are influential due to any reason, can remain in the final solution.

Taking this point into account, it is rational to think that collected facts have the potential to bring up an interconnected structure with the related conceptual entities as nodes and the relations between them as relations that can operate sensitively toward the inputs' constraints to yield finally the desired solution. It is due to this reason that such types of networks are preferred to be called constraint satisfaction nets.

Constraint satisfaction networks (CSNs) conceptualized in such a way, are believed to have a variety of applications in both rational and emotional problem solving, and optimization issues, such as commonsense reasoning, justification, intuitive judgment, and emotional adjustment as well (Hinton et al., 1984; Mittal & Falkenheiner, 1990; Glockner & Hodges, 2009). A salient point in all these cases is that they can hardly be realized in a symbolically significant format such as deduction, and instead a sub-symbolic format is required to show how interaction or exchange of information between the corresponding facts in terms of operations such as inhibition or excitation, can lead to the formation of a conjecture within which some of these facts get the opportunity to survive. The best alternative for such a format is a Hopfield Net (bidirectional associative memory) whose utility for a wide range of identification and recognition type problems have already been approved (Hopfield, 1982).

HOPFIELD NETWORK AS ALTERNATIVE FOR IMPLEMENTING CONSTRAINT SATISFACTION IN A NETWORKED MANNER

Constraint satisfaction provides a computational perspective on network function, where the network is viewed as simultaneously satisfying constraints imposed on by external inputs from the environment and the internal weights and activation states of the network itself. Hopfield showed that bi-directionally connected networks with sigmoid activation functions maximize the degree of constraint satisfaction. The Hopfield Network is a derivation of the Hebbian Nerve Cell Assembly(Hebb, 1949). The mathematical analysis of the constraint satisfaction network makes use of the energy function concept. The analogy of energy can be useful in understanding the dynamics of the network.

The symmetry of the connections in the Hopfield Network is important for its ability to "settle in" to an energy minimum. We assume that the network is initially presented with an input pattern, represented by an initial point on the energy landscape. The process of constraint satisfactions is likened to the system energy going to lower states as the unit activities are updated. The activities reach a steady state as the system energy settles into a minimum energy as well. The network energy is defined as:

$$E = -1/2\sum_j \sum_i x_i w_{ij} x_j \quad (1)$$

Where, x_i and x_j stand respectively for the i-th and the j-th nodes, and wij stands for the weight of the connection between these two.

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