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SUPPORT SYSTEMS FOR DECISION AND NEGOTIATION PROCESSES

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MULTI-MACHINE CONSENSUS BY NEGOTIATION

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Abstract: The problem of negotiation between machines can be modelled as a Quasi-morphism between the world and a corresponding representation. Upon this model communication can be modelled the 'dance' of communication, using a nontemporal and a temporal identification. A current implementation is described, and the preliminary results show that it is possible to reach consensus by negotiation between several systems.

Keywords: consensus, negotiation, artificial intelligence

1. Introduction

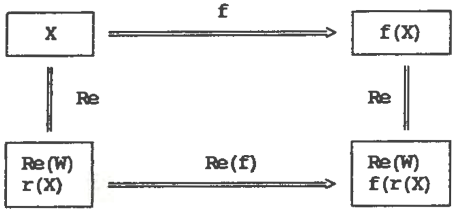
This paper deals with the problem of validation of communication between systems, and as a consequence of the models applied it is possible for the participating systems to negotiate through shared semantic values.

This problem of negotiation is partly solved by the use of a semantic coding, as the problem cannot be solved without a model of the applied communication and understanding. In this way it is possible to communicate with other systems without knowing the internal knowledge representation in the other machines.

This communication protocol is established for information transfer in particular between artificial intelligence systems, as these will have to use some kind of a standard model of interpretation. This has to be a very simple model, tranforming information to and from the artificial intelligence system's own internal knowledge representation.

2. Model

When developing a solution to the problem of negotiation through machine-communication, it is useful to specify how representation of information can be accomplished, and how this relates to the object that is being represented. This can be modelled as a Quasi-morphism, Holland (1986):



Model of representation

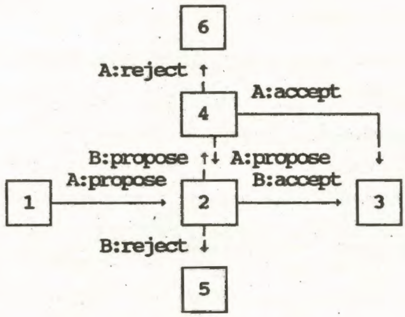
where X is an object in the domain of interest, Re specifies some method of representation, and r(X) denotes a represented object. If f stands for communication between two different entities, the elements in the model have to satify some constraints for the model to hold. There is only one Re(f), as this is the relation that specifies the consistent transfer between the two entities communicating. The problem can be stated shortly as

$$(X = f(X)) \text{ and } (r(X) \neq f(r(X)))$$

which simply states that the communication method used is not as neutral as it has to be.

Using the same representation is not a solution, as this will only specify the syntactical structure, and not how the transferred elements are to be interpreted. The problem lies in the semantic structure of the represented domain, as it is the interpretation of the transferred information that tells how the transferred elements are to be understood.

General communication can be modelled by the exception method, Wilensky (1983), where the entities are choosing a mutually known standard plan, and then the sender is transferring what he sees as differences from the standard plan. But what if the receiver does not agree? Then he will not be able to understand the transferred message in the right way. This can be modelled by the 'dance' of communication which is a slightly edited version of the original 'dance' of conversation, Winograd and Flores (1986), where the lines indicate actions that can be taken by the initial communicator (A) and the target (B). After the initial proposal from A to B, which specifies some plan, there are three alternatives: accept, reject, or propose another plan.



Model of communication

In order to select a plan to guide the communication, the first step for an entity is to send a proposal. The next step for the target is to respond, either by rejecting it, which will indicate that there is no basis for communication, or by accepting the plan, which is only possible if they have communicated before, thus knowing an appropriate plan; otherwise they start by negotiating a plan. This is done by making proposals and thus specifying refinements, one after another, until both parts can accept the plan.

When a plan is chosen, the transfer of information can be accomplished by implementing a read-eval-write loop. When one element is transferred, the target will respond with one of the options from the model of communication: accept which means that the sender can transfer the next element, reject, or propose which means that the receiver is returning its own interpretation of the received element. If the sender can integrate this interpretation in its own interpretation it can transfer the next element, otherwise they continue negotiating until they reach a mutual interpretation.

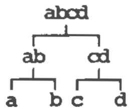
For the intention of a message to be understood unambiguously, it is necessary that it can be identified as having only one single semantic value. The semantic value can be defined as a hierarchical function of the symbols, where the semantic value of each symbol is defined by its position in the hierarchy, Trans (1991).

The knowledge representation can be very simple, as there are three kinds of symbols: primitive symbols, intermediate symbols, and target symbols. Each symbol can be defined as a triple

(name, super-symbols, sub-symbols)

where name is a specific identifier for each symbol, the underlining meaning that the element is a vector which can contain any number of symbols. Primitive symbols are the set of symbols that are valid in input sequences. Intermediate symbols are used in the processing of the input. Target symbols are the resulting interpretation.

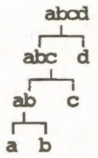
The identification is total when one topmost symbol is reached, otherwise it is not of any use. This hierarchical identification can be done in two modes as a temporal or as a nontemporal identification. The nontemporal identification is the basic step, where a set of data is identified as a holistic entity,



where the primitive symbols {a, b, c, d} will be identified as the target symbol 'abcd'. The semantic value of the identification is the root symbol of the tree, and every permutation of the elements will give the same value.

The problem with ambiguous identification can easily be solved by a disambiguation in four stages. First you identify an ambiguous symbol x, secondly you specify the number of possible different semantic values $\{x_1, \ldots, x_n\}$, thirdly you find a corresponding set $\{y_1, \ldots, y_n\}$ of unambiguous symbols, where the pair (x_i, y_i) relates to the same context, and fourthly you represent each pair of symbols (x_i, y_i) as subsymbols under a new intermediate symbol z_i.

The temporal identification is built upon the nontemporal identification, as the found values are used as elements in the temporal identification, where each of the values is used in their temporal order, one element at a time,



where the sequence of nontemporal symbols {a, b, c, d} are identified as the temporal structure 'a → b → c → d'.

When the participating systems have reached consensus on a mutual plan they can start to execute it. This is only possible if all the involved systems are using the same set of primitives, and in this way have a common basis to communicate on, as any higher order symbol can be defined from the primitives, and thus the domain will be the same for all the systems.

The actual communication is done by letting the system in control execute the next element of the current plan, and then ask the others for confirmation. The method applied is based on the possibility of mutual understanding of a plan, which is facilitated by a common set of communication primitives, and that the same method for understanding and interpretation is used by all systems involved.

3. Results

The communication-interface has been implemented as a rule based system, where all satisfied rules are executed in each cycle, and action removes the elements that are in the state subset from working memory. All duplicates are now removed from working memory, and the next cycle can begin. The knowledge hierarchy is transformed into a set of independent rules

IF <u>subtypes</u> THEN name

which means that if the entire set of subtypes of a name is in working memory, then remove the subtypes subset and place name in working memory. Thus, the identification of a sequence of symbols is performed through one or more cycles of the inference engine.

But high level communication is not only sending or receiving, there have to be some rules for the cyclic exchange of information, where each system involved can be described as a simple loop

with I and O as the sharing part, as I receives input from all the participants, and O sends output to all the other participants. P is the system in question, and the time slice of the cycle is one element of the current plan.

The thus implemented system has been used to structure the communication between three expert systems constructed from different paradigms. It has to be mentioned that all the participating programs were expert systems for planning, as it otherwise would have been difficult to use the temporal structure of the interface. The three programs were communicated through a small server that would receive a message from one system and send it to the two others.

The experiment showed that it is possible to use negotiation, but also that most of the cycles were used to negotiate the right interpretation. This is a consequence of the different knowledge representation used by the three programs, and it is only a problem when the programs are working on new problems. The more a problem is well known, the less time is used for negotiating, i.e the shared understanding of the already solved problems. This will make it easier for any of the participating systems to propose a plan and thus optimize the communication by avoiding negotiation.

4. Conclusion

The obtained results have shown that it is possible to reach consensus, and if the participants have shared knowledge of the domain in question, the use of negotiation can be useful.

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