# Distributed Case Based Reasoning Model with Semantic Intelligence

Chandrasekaran Subramaniam, V. D. Dhandayudhapani, Niveditha Narendhran, and Mohammed Nazim Feroz

***Abstract*—The objective of the work is to propose a case based reasoning (CBR) model with semantic intelligence for deciding a fine tuned solution from a number of distributed cases. A case model has been proposed to incorporate the needed data types and certificates through which the local or global authorities can reason out the solution. The n-tier model of reasoning can be performed using a case agency and broker components to file and adjudicate the results for the submitted cases. The machine learning is emphasized through iterative learning process with pre and post filters to fine tune the solution based on the context of the case. The semantic engineering is carried out to categorize the nature of the case in terms of basic informal constructs. An inherent hierarchy of the context is formed and based on the type and importance of the context, the scenario driven solution is identified by this proposed model. An airway passenger guidance system is considered to validate the model of case based reasoning with the help of decision tree technique.**

***Index Terms*—Case agency, case broker, case model, distributed decision, semantic intelligence.**

## I. Introduction

The recent artificial intelligence techniques have been extended to collaborative decision making through web based technologies. The correctness and the precision of any decision is based not only on the input domain data or values but also on the training methods. The reasoning techniques behind the decision vary from neural based approaches where the individual information bits are processed to case based approach where the whole case or scenario is analyzed. An enhancement over the CBR, the exact semantic meaning of the case in a particular context can also be applied to fine tune the results. The reasoning can be made by suitably adapting the submitted sources or cases that are most similar to the target case are not always the easiest to adapt, in particular when the similarity rests on surface features [1]. Since the adaptation requires additional knowledge which can be represented in the form of rules where new attribute values for the solution case can be specified [2]. Case Based Reasoning is based on retrieving the submitted cases by using similarity measures between terms; it is obvious that semantic knowledge can strengthen the results of this process. In the same context, the idea of combining ontology for the domain knowledge with CBR-based systems for knowledge management has been dealt by many approaches [3]. In the earlier reasoning techniques, scenario driven testing methodology was proposed in which various scenarios were depicted in a series of extensible mark up language (XML) files [4] for which an intermediate component, say middleware may be recommended to identify the similar data or case. The machine learning method was used for extracting the terms and events and further retrieving the other cases that are most similar to a given problem [5]. In the hybrid model of Fuzzy Case-Based Reasoning and Genetic Algorithm method, each factor has the same weight which means each one has the same influence on the output data that does not reflect the practical situation [6]. Genetics based approach faces a complexity problem in selecting the appropriate membership function and inclusion of constraint based penalty functions as their objective function. Different CBR models have been proposed out of which the AI model for computer game focuses on hierarchical task network in which the dependency of an action was driven in the form of a network through which the next move is decided based upon the opponents strategy [7]. A case-based reasoning combined with structural classifier is used to identify deforestation patterns in Amazonia where the object in the new images are mapped with the established patterns with their contexts [8]. In the case based reasoning models, the inherent semantic classification based on the transformation of the state variables are not considered. The main focus of the paper is to model the case itself and perform an iterative reasoning using the semantic intelligence (SI) embedded in the case statements.

The paper is organized as follows: Section II performs a case modelling suitable for imposing the certification processes and Section III describes the reasoning model with case dictionary and the phases of reasoning through which all the submitted cases have to undergo with pre filtering. Section IV illustrates the semantic intelligence concept that will be included to identify the correct category of investigation procedures before taking the decision. Section V brings out the implementation of the model through a case study where a scenario for an air way passenger guidance is sought and the corresponding n tier solution diagram are shown. The work concludes by bringing the limitations and the scalability of the model for heterogeneous cases with

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abnormal behaviour of each and every case object.

## II. Case Modeling

A case may be considered as a class object and it consists of attributes, declarations, reasons and certificates. The attributes may be a record or a product type composed of many basic data types. The type of an attribute has to be declared in a generic context and the needed declarations are to be mentioned. For example, consider a case where an application to avail ten days of leave is to be approved. The attributes would include fields like name, identification number and department of the applicant. The applicant has to obtain local certificates from local authorities like team leader, section in charge, session in charge and doctor in case of any medical treatment. In few cases a global certificate from an external source such as a foreign expert will be needed. All these fields can be put together and represented as a single object as shown in Fig. 1. The case reasoning model must consider the various acceptance and rejection possibilities as per the system or organizational policies. The cases may fail during approval and hearing phases even if the attributes and declarations of two cases are equivalent while the cases pass the case similarity test. If the global or local certificates of a particular case are not identical with that of the other case then the case may be rejected by the case broker during negotiation. When the attributes, declarations and certificates of two cases are the same and at the same time if the cases are from two different contexts then one case may fail without taking any decision on the problem. A case fails at the global level when it does not clear the similarity test and a local failure is one when the case passes the similarity test but fails at the reasoning level. The case that has cleared the initial screening level may fail during the specialization level due to an intermediate failure at the case submission level.

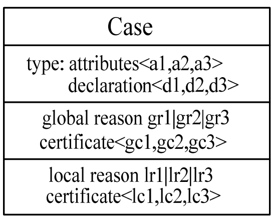


Fig. 1. Reasons and certificates in case

The computational model of CBR–SI can be derived if a set of ‘n’ cases are retrieved and checked. This may be determined based on the types of the needed attributes and their declaration duly certified by the authorities. If ‘m’ relevant cases are identified by the fulfillment of the attributes then the other (n-m) non compliance cases are considered as irrelevant and not accepted by the CBR system. The field wise comparison is enabled which checks with the help of the semantics placed in the engine for further relevance and correctness. Those permitted cases are stored in the case dictionary. Then the solution for the previously solved problems raised in the earlier cases is suitably modified based on the semantic knowledge base and the adjudication is disclosed after the negotiation with the client. The n-tier model of case presentation is proposed to solve the current problem. A case is received in the data layer and case type is determined by evaluating its attributes and declarations. If the reasons and certificates that accompany the case are both global and local are true then in mediator layer, the case agent and the case broker either accept or reject the case. For a case to be successful both the agent and the broker components must verify the case and even if one of them rejects the case, then the case is unsuccessful. The local, intermediate and global authorities evaluate the local and global certificates in the reasoning layer respectively. Based on the results of the above layers a decision is declared in the adjudication layer by the distributed CBR system. The computational intelligence is distributed and it is iteratively applied in various layers and result is obtained with the help of rewrite rules and corresponding certificate verification as shown in Fig. 2.

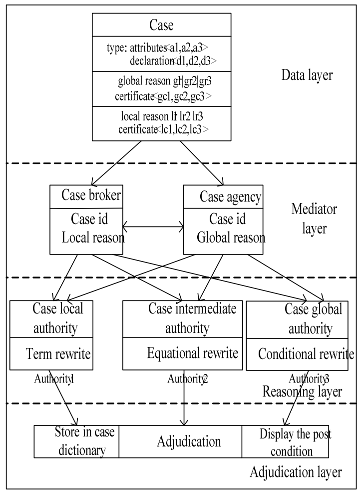


Fig. 2. Case based reasoning framework

## III. Case Based Reasoning Model

Fig. 3 depicts a situation where a set of ‘n’ cases enter the system. Those cases that are stored in the memory are retrieved to check for relevance with the incoming cases. The cases which are relevant are retained and they enter into the Case Based Reasoning system. There are four CBR phases and for each one of these phases there are four processes in a cyclic environment which perform the evaluation for ‘n’ cases in an iterative manner. The hearing phase maps the solution from the previous case for the required problem. The solution adapts to the new situation and fits itself in. Next it enters into the reasoning phase where it is tested if the solution works good for the case under study. Once this mapped solution is found to be successful for the given problem, then the problem along with the solution is stored in the case dictionary for future reference.

If a subsystem calls a petitioner and files a case, then the case is primarily registered and then is subjected to a screening process. In this process the registered case is checked for its relevance, if the case is relevant it will be sent for further processing. Those cases that are not relevant are removed from the system. Now the case enters into the semantic intelligence system. Here all its fields and attributes are collected for the registered case. Then the attributes list of previously stored cases will be retrieved and will be cross checked with the registered case for its relevance. This checking process will be continued until relevant results are obtained by cross checking for the registered case. Once the relevance is found out the reasoning process will be instantiated. In the reasoning process, the results of different cases will be checked and a feasible solution is obtained for the registered case with semantic intelligence.

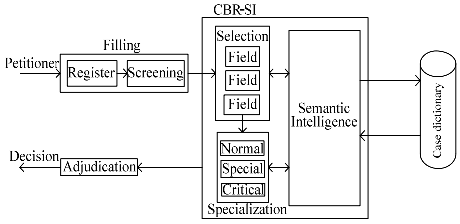


Fig. 3. Stages of case based reasoning

## IV. Semantic Intelligence

Semantic intelligence is an approach to natural-language processing and unstructured information management. The semantic intelligence performs the task of computing in such a situation to find a solution to the case in a tuned manner. A case submitted to the semantic intelligent engine can be considered as a tuple, < subject, object, relation, predicate, effect> where S, O, R, P, E are the respective sets from which a case can be constructed. After applying the semantic intelligence the decision is mapped to any one of the member in the context set C. A subject at state *s* in pre-condition before applying the predicate changes in the post condition to state $s^1$ such that $(s, s^1) \in S$. Similarly an object in state *o* as its pre condition, changes to state $o^1$ in its post condition such that $(o, o^1) \in O$ due to the application of the same predicate $P_i$. A relation *r* in the pre condition gets transformed to $r^1$ in the post condition after applying the predicate such that $(r, r^1) \in R$. For example, considering the statement "generator loads motor" where the generator, motor and load are the subject, object and predicate respectively. In the pre condition the motor is in OFF state. After it gets loaded its state changes and it is switched to ON state. There is an allowed change in the state of the object when the predicate is applied. For instance, considering the statement "Employer loads employee" the states of the subject and object do not change. But a special case is obtained considering the statement "Server loads data". When the subject server loads object data the state of the relationship between the server and data changes from connected to disconnected or vice versa. Hence semantic intelligence may be viewed in the form of categorizing the state changes of subject, object and relations which is similar to context change.

Pre condition : $s \in S,\ o \in O,\ r \in R$
Post condition: $s^1 \in S,\ o^1 \in O,\ r^1 \in R$
Context: $C_1, C_2, C_3, C_4 \ldots C_n$

When there is no change in the state of subject '*s*' or object '*o*', or relation '*r*' in their post conditions when compared to those of their preconditions, then it can be categorized into a context $C_1$. If there is a change in the state of one of the fields from subject *s* or object *o* or relation *r* in the post condition states when compared to their precondition state then it can be categorized into context $C_2$. If any two fields change in the post condition on applying the predicate then it is context $C_3$. If all the three fields change on applying a predicate then it is classified as context $C_4$ and so on.

### A. Airway Passenger Scenario

A passenger whose is of Indian origin wishes to travel to a foreign country. Considering the past records of the passenger it can be found that the passenger has already visited the same country thrice. The passenger also holds a valid visa to the same country. The passenger is aged 35years and he is a qualified chemical engineer. However at present there is crisis in the foreign country due to a bomb blast. On the other hand the passenger has an emergency and he must travel to the same country immediately in order to solve his own disputes. Here the case agency approves his request but when the case is taken to the case broker the same case is rejected and the passenger is not allowed to travel abroad.

This case is put into the case based reasoning system. The case or request has to be passed through various stages and finally get approved to travel. Once it clears this phase it is then passed through a semantic intelligence system where the case is intelligently analyzed and gets ready for the decision making process. For the above scenario the case that has to be filed will have the following case specifications as shown in the box:

Case: passport check
Attributes: Passenger name, age, nationality, profession
Declarations: Number of visits to the country
Local certificate: Passport
Local reason: Emergency
Global certificate: Visa
Global reason: Crisis
Case agency: airport authority (home land)
Case broker: Immigration authority (foreign nation)

Pre condition is that the passenger has visited the country thrice and the predicate is that the passenger is currently applying for travel to the same foreign nation yet again. The context is that the passenger wants to travel due to his personal emergency reason

### B. Statement

If there is some event like terrorism in the foreign country then the foreign country is in emergency. When the passenger is in an emergency situation to travel, then permit him to travel. If the foreign country is in emergency due to the passenger, then don't permit him to travel. Only after the case agency/broker clears the case it can be taken to the immigration authority. The passenger is permitted to travel only if the case is cleared by the immigration authority. The inferences that can be arrived from the above case is enumerated below using the basic propositional logic operations.

Terrorism in foreign country $\rightarrow$ Emergency in foreign Country (1)
Terrorism in foreign country

Therefore Emergency in foreign country // Modus ponens
$\sim$ Emergency in foreign country $\rightarrow$ Clear immigration (2)

$\wedge$ Passenger in emergency $\rightarrow$ Case agency approves
$\sim$ Emergency in foreign country $\vee$ Passenger in emergency
Therefore Clear immigration $\vee$ Case agency approves
// Constructive dilemma

Emergency in foreign country→ ~ Clear immigration (3)

~ Clear immigration → ~Permit to travel
Therefore Emergency in foreign country→ ~ Permit to Travel //
Syllogism

Case agency approves→ Clear immigration (4)

~ Clear immigration
Therefore ~ Case agency approves // Modus Tollens

Emergency in foreign country↔ Passenger emergency (5)

// False

Visa obtained→ Permit to travel (6)

Clear immigration→ Permit to travel
Visa obtained ∧ Clear immigration→ Permit to travel
// Conjunction

By applying the equivalence rules, the case can be reasoned out to get a fine tuned solution. The case based reasoning algorithm for distributed cases in multiple layers is shown below:

### C. Case Based Reasoning

```
Let total cases be 'n'
Let the relevant cases be 'm' after local filtering based on
CIF such that m is a subset of n .
Disregard the (n-m) cases
Let the number of similar cases in the dictionary be 'd'
Let a_i be an attribute of m with <a_1, a_2, a_3.....a_p> and
b_j be the attribute of similar cases d in the dictionary with
attributes <b_1, b_2, b_3.....b_q>, where p>q
Find the common attributes between m and d

for i,j € Z // Z is a set of integers//
Select a_i
Select b_j
Compare selection fields// Profession, Frequency of travel //
Compare special fields // Global reason, Local reason //
Next i
Next j
// Case broker and agency phases//
for k
Context_k = {
Precondition: filing [a_1, a_2, a_3..] // case registration phase //
Post condition: hearing [h_1,h_2, h_3..] // case negotiation //
}
// Semantic intelligence applied //
reason[ r_k ] => context [c_k]
context [c_k] => decision [d_k]
{
call conditional rewrite,
if C_i is an equation u_i=u_i' or a membership u_i:s, then
```

$$vars(c_i) \subseteq vars(t) \cup \bigcup_{j=1}^{i-1} vars(c_j)$$

```
call term rewrite,
if C_i is an equation u_i=u_i' or a membership then u_i is an
m-pattern
```

$$vars(u_i') \subseteq vars(t) \cup \bigcup_{j=1}^{i-1} vars(c_j)$$

```
}
decision = pass || neglect
next k
store decision in case dictionary // Store the solution //
if decision_i = pass_i
Adjudicate to the user // Adjudication phase //
else display 'post condition'
end
```

## V. Implementation and Results

Bayesian networks are acyclic directed graphs in which nodes represent random variables and arcs represent direct probabilistic dependences among them. The structure of a Bayesian network is a graphical, qualitative illustration of the interactions among the set of variables that it models. The structure of the directed graph can mimic the causal structure of the modeled domain, although this is not necessary. When the structure is causal, it gives a useful, modular insight into the interactions among the variables and allows for prediction of effects of external manipulation. In the following Bayesian network we have developed a model for an airway passenger guidance system in which the passengers are checked by the case broker and the case agency. The results of the two subsystems are then combined to take a new decision.

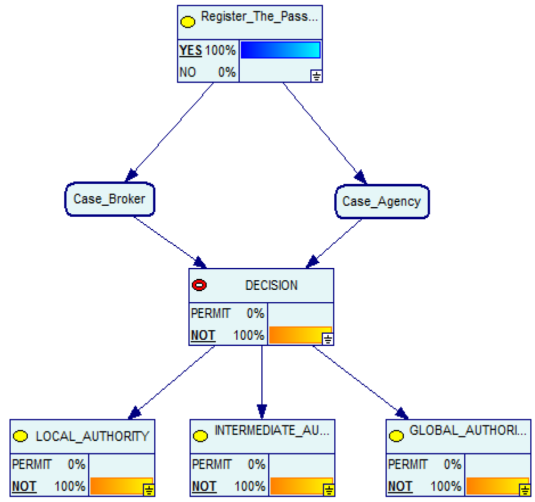


Fig. 4. CBR in Airway passenger guidence system

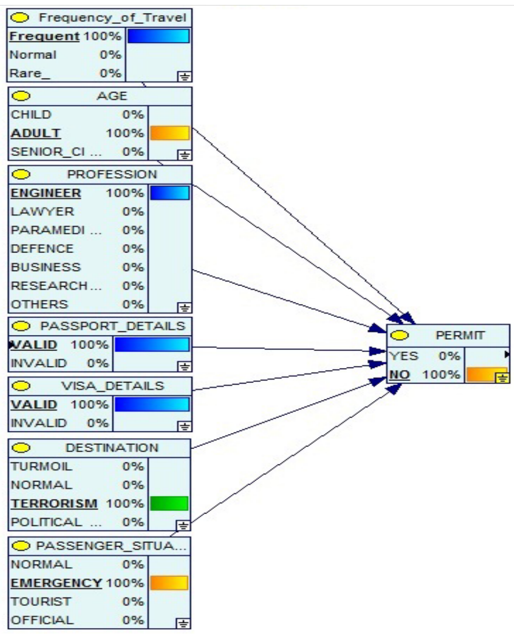


Fig. 5. Travel permission submitted to case broker

The passengers are first registered and the formal checking is completed. The passenger will be evaluated by the case broker and case agency where both of them maintain records of the case. The case which is related to the present parameters is retrieved along with their stored solution. The results of both the case broker and case agency will be taken into account when the decision is made as shown in Figure4. The passenger details are retrieved by using the passport number. The passenger details such as passport details and visa details are first checked and validated, the passenger will be allowed to travel only if he has a valid passport and visa. After this the passenger's age, profession, frequency of flying, situation of travel and the current condition of the destination country are retrieved and a separate evaluation will be made by the case broker case agency. The result from both the Case Agency and Case Broker will be retrieved and a decision will be made which will be delivered to the authorities as shown in Fig. 5.

## VI. Conclusion

The case based reasoning model for distributed cases is proposed in the paper and the work assumed an n-tier model through case broker and case agency components. The case is modeled with its attributes and reasoning factors through local and global certificates. The semantic intelligence is applied using propositional logical constructs and then rewrites mechanism to decide the best decision based on the contexts. The Bayesian network is applied for a passenger's immigration and travelling problem using the proposed model and the results are arrived whether to permit the passenger to travel or not. The limitation of the work is based on the heterogeneous case with specific certificates either local or global that makes the reasoning to be updated periodically. The effective power of CBR depends on the synchronization of communication between the broker and agency components through the restricted channel.

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