An Extended Assumption-based Truth Maintenance Method for Time Varying Situations

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Abstract

An ATMS(Assumption-based Truth Maintenance System) has been widely used for maintaining the truth of information by detecting and solving contradictions in rule-based systems. But the ATMS can not correctly maintain the truth of the information in case that the generated information is satisfied within a time interval or includes data about temporal relations of events in time varying situations, because it has no mechanism manipulating temporal data.

In this paper, the extended ATMS method is proposed, which can maintain the truth of the information in the inference system using information changing over time or temporal relations of events. In order to maintain contexts generated by relations of events, the label representation method is modified, the disjunction, conjunction simplification method in the label-propagation procedure and nogood handling method of the conventional ATMS are modified, too.

1. Introduction

Conventional knowledge-based systems maintain its knowledge base that contains information about their environment, which is updated to reflect the perceived changes in the environment. The set of facts in the knowledge base is called the beliefs of the system. New beliefs may bc added to the knowledge base either through observation or through inference using the beliefs in the knowledge base. But new observations may lead to conflicts with the beliefs in the knowledge base, or new beliefs originated during inference may show that some of the beliefs in the knowledge base are not plausible or are mutually inconsistent. Systems for overcoming these problems are called Truth Maintenance Systems (TMS)[1]. Among these systems, the JTMS (Justification-based TMS) and the ATMS (Assumption-based TMS)[2] are mostly used. The difference between justification-based and assumption-based TMS's lies in the treatment of contexts. While there is always one context in which nodes can be in or out in the JTMS, there are many contexts in the ATMS. Generally, the ATMS that can switch rapidly between contexts, is more widely used than the JTMS.

In time varying situations that the beliefs change, the truth maintenance system can not correctly maintain a knowledge base, because it doesn't consider relations among temporal data. To resolve these problems, a new approaches were suggested such as the TRMS (Temporal Reason Maintenance System)[3] suggested by Dean and McDermott, the ATMS[4] suggested by Cao

Wen. The TRMS using a JTMS method can't maintain multiple contexts, and the ATMS suggested by Cao Wen can't maintain a new context that is generated through inference about temporal relations of events.

An Extended ATMS method that can maintain multiple contexts is proposed by temporal relations of events in time varying situations that the truth of information changes over time as modifying the previous label propagation of the ATMS. In the proposed method, The disjunction and conjunction simplification procedures are newly defined using time intervals and temporal relations of events, and the nogood handling mechanism is modified to maintain correctly the truth of propositions changing over time.

2. The previous work

When new observations may lead to conflicts with the beliefs in the knowledge base, the truth maintenance system can maintain continually the truth of information as resolving the conflicts.

ATMS make the distinction between assumptions and facts. Assumptions are data which are presumed to be true unless there is evidence of the contrary. Facts are primitive data that is always true, or that can be derived from other data or assumptions. The ATMS records such dependencies through justifications. Each datum is stamped with a label consisting of the list of environments under which it holds. When a new justification for a datum is provided, its label is updated with the label of the left-hand-side of the justification. An environment is inconsistent if it enables to derive a special datum representing the contradiction. It is called a nogood. When such an environment is discovered, it has to be removed from all the labels.

An ATMS label that is the minimal assumption sets from which the node is derivable plays a major part in the ATMS. The size of labels may greatly influence the efficiency of the ATMS. So the ATMS must keep the size of label as small as possible, this leads to a label simplification problem that is composed of the disjunction and conjunction simplification. But these processing are accomplished without temporal information in the previous ATMS. In time varying situations, justifications should contain the temporal data and the information of temporal relations of events. But the previous ATMS can't correctly maintain the truth of information because it has no mechanism that can manipulate these data. An example of the disjunction simplification in the previous ATMS is as follows.

① If A in the period 18:00 - 20:00, then C
② If A and B in the period 17:00 - 21:00, then C
③ If A and B in the period 19:00 - 21:00, then C

When the justification is generated by inference engine using above three rules, a previous ATMS maintains the label of C as {{A}}. Namely, the label of C becomes {{A}} as a result of the disjunction simplification between {A} and {A∧B}. But if the above three rules are considered in detail, the label of C can be simplified into {A} by ① and ② rules, but can't be simplified by ① and ③ rules., because the interval of ③ doesn't include the interval of ②. So, the previous ATMS can't be used in case that assumptions have the time interval. For the purpose of overcoming these problems, Cao Wen maintains the label as appending time intervals to each assumption. But this method can't maintain the information that is generated by temporal relations of events. In other words, it can't represent before and after relations of events as a label, maintain the truth when conflicts are occurred among these data. So, a new method is required that can represent the temporal relation of events and handle the contradiction between these relations.

3. The proposed method

3.1 The representation of label

The label is represented by appending the time interval to the assumption as follows.

(Assumptions) [t or w] (interval)

In the above representation, t means that assumptions hold throughout the interval, w means that assumptions hold within the interval.

Whenever justifications that include the information about relations of events are inputted, a node of new type that is called the temporal type node is generated. This node represents temporal relations of events. Later, if a contradiction is discovered in temporal relations of events, the information of this node will enable a conflict resolution.

Temporal relations of A after B and A during B are different. The former means that the starting time of A is greater than B's, and the latter means that the starting time of A is greater that B's and the ending time of A is less than B's. In the proposed method, the temporal relation between two events is represented as the relation between the starting and the ending time of events in a label.

```
(R1 if (E (A) ?i1)
       (E (B) ?i2)
       (> (st ?i1) (st ?i2)))
(R1 then C)
```

The above rule R1 means that when A occurs in ?i1 interval and B occurs in ?i2, and the starting time of A is greater than B's, namely, A occurs after B occurred, the fact C is implied. The rule is represented by the NEO form that is an artificial intelligence programming tool.

In this case, the label of C is as follows.

```
C : {{A, B, n1}}
n1 : (t> (st ?i1) (st ?i2))
```

In above representation, the temporal type node n1 is separately maintained, and we can resolve contradictions between temporal relations of events by using the node.

3.2 The label propagation

An ATMS label is a minimal set of assumption sets from which the node is derivable. It describes how a node ultimately depends on assumptions. Each label of each node must be consistent, sound, complete, and minimal with respect to justification. So, the simplification process in label-propagation procedure must be executed to satisfy this rule.

In the proposed method, the label is maintained minimally by considering a set relation of intervals, the temporal type node as well as assumptions.

An example of simplification rules in the proposed method is as follows.

① (A, B, n1) ∨ (A, B, C, n2)
→ (A, B, n1)
if (n1 ⊆ n2)
(A, B)[w](t1 t2) ∨ (A, B, C)[w](t3 t4)
→ (A, B)[w](t1 t2)
if ((t1 t2) ⊆ (t3 t4))

② (A, n1) ∧ (A, B, n2)
→ (A, B, n2)
if (n1 ⊇ n2)
(A)[w](t1 t2) ∧ (A, B)[w](t3 t4)
→ (A, B)[w](t3 t4)
if ((t1 t2) ⊇ (t3 t4))

The first formula expresses a case of the conjunction simplification, and the second expresses a case of the disjunctions. In these formulae, the node n1, n2 represent the temporal relation of events as the

temporal type node, and the simplification process in this case is implemented with considering inclusion relations of these nodes as well as assumptions. If the node n1 is (t>= (st A) (st B)), and the node n2 is (t= (st A) (st B)), the node n1 includes the node n2. An inclusion of time interval is decided by comparing each time points. For example, if t1 is less than t3 and t2 is greater than t4, the interval (t1 t2) includes the interval (t3 t4).

3.3 The nogood handling

Whenever a nodes label has been computed, an ATMS checks each assumption set to eliminate all inconsistent assumption sets. But, since an ATMS can't manipulate the temporal relation of events, it can't correctly resolve conflicts among temporal data. In this paper, to eliminate a contradiction caused by the varying data, its more specific instances (i.e, its supersets) are newly defined.

A superset testing consists of three parts testing. For the assumption set part, it is a normal explanation in the set theory as : A1 $\supseteq$ A2. For the interval part, after the interval is converted into a set, the superset testing is executed as the assumption set part. In case that the label of C is ((A)[w](9 12)), when the ((-A)[w](9 11)) is occurred, the label of C is not eliminated, but modified into ((A)[w](11 12)). For the temporal relation part, it is implemented by considering relation between the starting and the ending time of events. In case that the label of C is ((t>= (st A) (st B)), if it is discovered that the ((t= (st A) (st B)) is nogood, the label of C is modified into ((t> (st A) (st B)).

3.4 The relation between the inference engine and the truth maintenance system

In the proposed method, the relation between the inference engine and the truth maintenance system is shown in Figure 1. The time engine manipulates temporal data and event generated by temporal reasoning. The processed data in this part is used in the inference engine. After the TMS part received conclusions and contradictions between data from inference engine, it maintains these data as a label and a nogood set. Namely, it maintains the truth of information using justifications taken from the inference engine, and eliminates contradictions by the nogood handling. Later, when the inference engine queries about nodes, the TMS returns the belief about it.

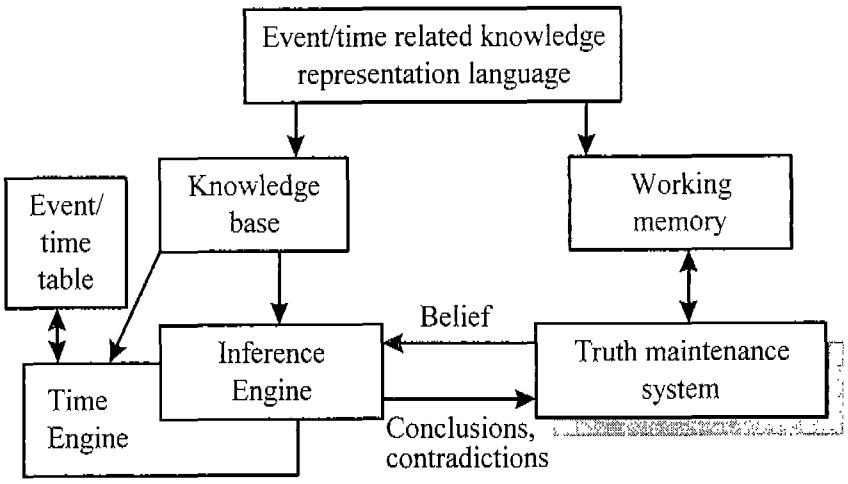

Figure 1. The relation between inference engine and truth maintenance system

4. An example of the proposed method

The following rule R2 means that during the weather is cloudy, if the aircraft is detected, it is an all-weather aircraft. This rule is represented and implemented by the NEO.

```
(R2 if (E (?x is-found)
        (weather status cloudy)))
(R2 then (?x type all-weather-aircraft))
```

When the rule R2 is executed, the generated justification is as follows.

{{C}, {A, B, n1, n2}}
A : (weather status cloudy)
B : (f1 is-found)
C : (f1 type all-weather-aircraft)
n1 : (t>= (st B) (st A))
n2 : (t>= (et A) (et B))

In this representation, the first element {C} is consequents, and the other element is antecedents. Two nodes n1 and n2 are automatically generated as temporal type nodes.

The label of C is represented using this justification as follows.

C : { (A, B, n1, n2) }

Later, if it is discovered that the temporal relation between A and B is invalid, every environments that include node n1 or n2 are eliminated from each label.

The rule R2 infers that the detected aircraft is all-weather aircraft if the aircraft is detected during the weather is cloudy. Namely, it is not executed in case that the weather becomes cloudy after the aircraft is detected. Later, if it is discovered that the weather become cloudy after the aircraft is detected, we must eliminate the fact that the aircraft is all-weather aircraft. To enable these facilities, the temporal type node as shown in above, is used.

Because the previous ATMS can't represent and maintain before and after relations of events, the label of C is represented as {(A, B)}. So, when the contradiction between these relations is detected, the previous ATMS can't do anything. Namely, when the node n1 become nogood, it can't eliminate the label of C. The Cao Wen method can't also maintain the truth in these situations because it consider only the relation of intervals.

5. Conclusion

In this paper, the extended ATMS method is proposed, which maintain the truth of the information about temporal relations even though conflicts occur in temporal relations of events as well as assumptions stamped with time intervals. For this purpose, time intervals are appended into assumptions, and represented the label using temporal type nodes that compare the relation between the starting and the ending time of events. Also, the disjunction, conjunction simplification procedures were modified, and the nogood handling mechanism was expanded. Through these processes, the truth of the information about temporal relations of events and intervals of assumptions in time varying situations, can be maintained correctly..

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