Conflict Resolution in Overlapping Information Fields for Context-based Activity Design

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Abstract: Norms are a set of rules that govern the behaviour of human agent, and how human agent behaves in response to the given certain conditions. This paper investigates the overlapping of information fields (set of shared norms) in the Context State Transition Model, and how these overlapping fields may affect the choices and actions of human agent. This paper also includes discussion on the implementation of new conflict resolution strategies based on the situation specification. The reasoning about conflicting norms in multiple information fields is discussed in detail.

1 INTRODUCTION

Information field is a set of shared social norms that governs the behaviour of a group member in an organised fashion (Stamper et al., 2004). For instance, a human agent may belong to different social groups and each has its own shared set of norms referred to as fields of norms. The overlapping of these fields of norms may introduce conflicts. So, in order to resolve these conflicts, a strategy is required to decide which norm should be applied. The aim of this paper is to resolve the conflicting norms, which may affect the transition of activity states in the Context State Transition Model (CSTM). The reminder of this paper presents a brief overview of the Context-based Activity Design (CoBAD), followed by the representation of norms, then conflict resolution strategies, the analysis of conflicting norms in multiple information fields, discussion and conclusion.

2 CONTEXT-BASED ACTIVITY DESIGN (CoBAD)

Context Ontology Model (COM) is one of the important elements in this study that provides a well-structured scheme for semantic representation of context identifiers, which enables context reasoning. The COM consists of three top-level entities (e.g., Extrinsic Context, Intrinsic Context, and Interface Context), which corresponds to an activity system. The Extrinsic Context refers to its surrounding environment, the Intrinsic Context describes the attributes of human agent, and the Interface Context refers to its activities involving the interactions with its environment. This captures an activity system as an interaction (Interface Context) between the agent (Intrinsic Context) and its surroundings (Extrinsic Context) that potentially results in changes to all three contexts that can be applied into common CoBAD (Zainol and Nakata, 2010). The CoBAD represents the use of context and its dynamic changes in the interactive systems. Two inference mechanisms have been introduced in this study: (i) Activity Reasoning (AR) rule specifies the activity reasoning of human agent; (ii) State Transition (ST) rule specifies the possible activity states that human agent can perform, and thus will affect the choices of the next activity state. Typically, both of them are defined as a set of a condition-action rule. The AR rule may be described as having the following general form:

$$[\text{ExtrinsicContext} \wedge \text{IntrinsicContext}] \rightarrow [\text{newExtrinsicContext} \wedge \text{newInterfaceContext} \wedge \text{newIntrinsicContext}]$$

when newInterfaceContext $\neq 0$;

The left hand side (LHS) of the AR rule refers to the situational conditions, while the *action* on the right hand side (RHS) of the AR rule consists of a new context of any category when new interface

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context is not empty. A special type of AR rule is ST that can be expressed as follows:

[ExtrinsicContext ∧ InterfaceContext ∧ IntrinsicContext] → [newInterfaceContext]

The LHS of the ST rule refers to the current activity state (Interface Context) of a human agent in a specific situation. The RHS of the ST rule represents the updates to the current activity state, which refers to next activity state (new Interface Context). If the LHS of a rule become true then the action corresponding to the specific rule is triggered. This in turn results in the changing of activity states. In order to design the transitions of activity states, we apply the method of state space representation. We proposed the Context State Transition Model (CSTM) that consists of a set of activity states and ST rules. However, this model lacks the ability to capture and represent the meta-level contextual specification. Therefore, a semiotics theory, such as norms and information field (IF) theory is incorporated in the CSTM, which represent the aspect of default and dynamic norms that governs the behaviour of a human agent in a specific situation. Such set of norms should be modular and should be dynamically added and removed with a possibility to specify preferences between the conflicting norms.

3 TAXONOMY OF NORMS

Norm is a field of force that makes inhabitants of a community to behave or think in a particular way (Stamper et al., 2000). Humans are seen as agents and their actions are influenced by the forces that are present in information fields (IFs), and these forces originate from the norms that are shared within the community (Gazendam, 2004). In this study, the concept of norms and the IFs paradigm are adopted to represent the aspect of norms, which govern the behaviour of a human agent in the CSTM. There are four types of norms: perceptual, evaluative, cognitive and behavioural (Stamper et al., 2000). Based on this, we further define them as follows: (i) *perceptual norms* are concerned with how human agent acts in accordance with his/her perception based on facts. They can be represented as *conditions* (C_j); (ii) *cognitive norms* represent the aspect of human agent's belief about actions. They can be represented as *activities* (A_i); (iii) *behavioural norms* determine how a human agent should behave and define what a human agent is expected to do under a given situation. These norms are represented by ST rules: $A_i \wedge C_j \rightarrow A_n$, where both A_i and A_n are activity states and C_j is a condition; and finally, (iv) *evaluative norms* are used to represent the aspect of choices or preferences of a human agent to choose his/her next action based on the available context information. They can be represented by a set of activities or conditions $pref(A_1) > pref(A_2) >, \ldots, > pref(A_n)$, where A_1 is the most preferred activity than $A_2, \ldots, A_n$, or $pref(C_1) > pref(C_2) >, \ldots, > pref(C_n)$, where C_1 is the most preferred condition than $C_2, \ldots, C_n$. Based on our observation, the intersections of two or more IFs in the CSTM may introduce conflicts among norms. In other words, an agent can be affected by more than one information fields (IFs) at one time. One possible way to resolve a conflict is to set precedence of norms in the shared norms. By setting the precedence of norms in the IFs, a human agent is expected to be able to comply with an appropriate norm based on the situation.

4 CONFLICT RESOLUTION STRATEGIES

In order to resolve a conflict, a strategy is required to select a rule from the conflict set for firing. The most popular strategies used in many of the existing production system (PS) are random, recency, specificity, and refractoriness. However, none of them support the preference setting of norms. To overcome this problem, we proposed new strategies and divided them into three main situations:

- Situation 1: when the information field 1(IF 1) is more dominant than the IF 2 $[d(IF_1) > d(IF_2)]$ or vice versa then apply dominant IF. The strategies are: (i) *DominantIF*: choose the rule from dominant IF; (ii) *Dominant-PreferredOutcome*: choose the rule that result in preferred outcome specified by evaluative norms in dominant IF; (iii) *Dominant-PreferredCondition*: choose the rule that contains preferred condition specified by evaluative norms in dominant IF; (iv) *DominantRuleCondition*: choose the rule that contains condition in dominant IF.
- Situation 2: If no dominant IF specified $[d(IF_1) = d(IF_2)]$ then apply any IF. These strategies are listed as follows: (i) *PreferredOutcome*: choose the rule that result in preferred outcome in any IF; (ii) *PreferredCondition*: choose the rule that result in preferred condition in any IF.

- Situation 3: If the strategies specified in both situation 1 and 2 failed then apply the standard strategies, such as random, recency, specificity, and refractoriness.

5 THE ANALYSIS OF CONFLICTING NORMS

In order to analyse the reusability of CSTM into different set of norms, we present three simple diagrams. Firstly, we analyse the base information field (IF) (see figure 1), followed by the analysis of the overlapping a non-dominant IF (figure 2), and a dominant IF (figure 3) onto the base IF. To perform reasoning, we applied a production system (PS) and set the ordering of strategies as follows: DominantIF, DominantPreferredOutcome, DominantPreferredCondition, DominantRuleCondition, PreferredOutcome, PreferredCondition, Random, Recency, Specificity, and Refractoriness. The sequences of rule firing and actions are presented in Table 1, 3 and 5.

5.1 The Base IF

Figure 1 shows a diagram that represents the default activity state transitions for base IF. It consists of a set of activity states $\{A_1, \ldots, A_9\}$, conditions $\{C_1, \ldots, C_9\}$, and state transition (ST) rules $\{ST_1, \ldots, ST_{13}\}$ that specify the set of possible activity states. Depending on which activity state the human agent is in, different ST rules are available for a human agent to be triggered. We assume activities are mutually exclusive. i.e., a human agent cannot be engaged in more than one activity at any time. Table 1 illustrates an example of PS model solution for base IF. It summarises the sequences of rule firings and actions in the example, and the stages of working memory (WM) in the execution along with the directed graph of the state space (refer figure 1). The first column shows the cycle of PS. The second column describes the information content in the WM, which can be further extended into two subsections: the first sub column contains current context state (facts) and the second sub column contains the derived state as the result of executing the ST rule in the preceding cycle.

Next, the third column refers to the potential rules that can be fired in the conflict set, while the fourth column describes possible strategies that would be employed to fire the chosen rule, however, if no rules are applicable then stop. Finally, the rule that has been fired is presented in the last column, while the action (facts) in the ST rule is then added into the WM to be reused in the next cycle.

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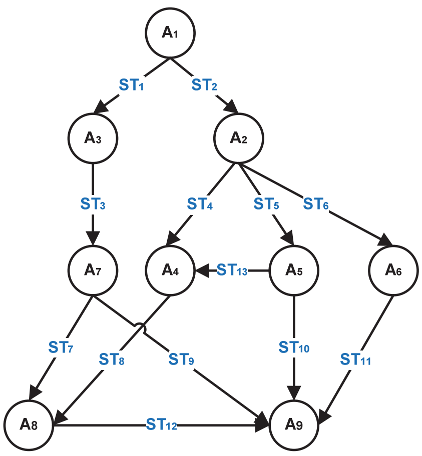
Table 1: Trace of a production system for base IF (IF_0).

Cycle	Working Memory		Conflict set	Conflict Resolution	Rule fired
	IF_0	derived facts			
0	C_2, C_5	A_1 (initial state)	ST_2	NULL	ST_2
1	C_2, C_5	A_2	ST_5	NULL	ST_5
2	C_2, C_5	A_5	NULL	NULL	HALT



State Transition Rules
$ST_1: A_1 \wedge C_1 \rightarrow A_3$
$ST_2: A_1 \wedge C_2 \rightarrow A_2$
$ST_3: A_3 \rightarrow A_7$
$ST_4: A_2 \wedge C_3 \rightarrow A_4$
$ST_5: A_2 \rightarrow A_5$
$ST_6: A_2 \wedge C_4 \rightarrow A_6$
$ST_7: A_7 \wedge C_5 \rightarrow A_8$
$ST_8: A_4 \wedge C_6 \rightarrow A_8$
$ST_9: A_7 \wedge C_8 \rightarrow A_9$
$ST_{10}: A_5 \rightarrow A_9$
$ST_{11}: A_6 \wedge C_9 \rightarrow A_3$
$ST_{12}: A_8 \rightarrow A_9$
$ST_{13}: A_5 \wedge C_7 \rightarrow A_4$

Figure 1: An example of CSTM with the rules of state transition for base information field.

Assume that when we start the rules and facts are loaded into production rules and WM, respectively (refer table 1). Given that A_1 represents the starting activity state. Based on the known facts in the WM, we apply a forward chaining, which is reasoning from facts to the conclusions resulting from those facts. The inference begins from the top of the rule, ST_1, and goes on downward until the first true condition is found. In the first iteration (cycle 0), the recognise-act cycle (RAC) matches the current state (conditions): C_2, C_5 and A_1 in WM against the ST rules. At this stage, the rule, ST_2 matches with the facts (conditions) in the WM. Therefore, the rule, ST_2 is fired and its action, A_2, is asserted in the WM. This in turn affects the transition from activity state, A_1 to A_2. The second iteration (cycle 1) uses this information and the updated facts: C_2, C_5 and A_2 would match with the rule, ST_5. The rule, ST_5 is then fired and the activity state A_5 is then added in the WM; indicating a transition from activity state, A_2 to A_5. Finally, in cycle 2, the execution halts as no more rules to fire.

5.2 The Overlaying of Non-dominant IF to Base IF

Next, we analyse the overlapping of a non-dominant information field, e.g., information field X (IF_x) to base information field (IF_0). When these two IFs overlap with each other, the IF_x will brings different set of norms (e.g., facts, rules, preferences) into the existing set of norms of IF_0, as presented in table 2. As a result, these set of norms will then introduce conflicts to some extent.

Table 2: A set of norms added from the IF_x.

Types of norms	Norms added from the IF_x
Behavioural norms	-
Evaluative norms	$pref(C_1) > pref(C_2)$
Cognitive norms	A_9
Perceptual norms	C_1, C_8

Table 3 illustrates an example of PS model solution for activity state transition based on both IF_0 and IF_x. In this table, another sub column is added into WM's column, which contains temporary context information introduced by another IF. Again, given that A_1 represents the starting activity state, the inference begins from the top of the rule, ST_1, and goes on downward until the first true condition is found. In the first iteration (cycle 0), the RAC matches the current state (conditions): C_1, C_2, C_5, C_8 and A_1 in the WM against the ST rules. At this stage, only two rules: ST_1 and ST_2 matched with the facts (conditions) in the WM. At this stage, only two rules: ST_1 and ST_2 matched with the facts (conditions) in the WM. Hence, the conflict set consists of the following information: $\{\langle ST_1, A_1, C_1\rangle, \langle ST_2, A_1, C_2\rangle\}$. In order to resolve the conflict, a strategy *PreferredCondition* is applied to select ST_1 for firing because of the following explanation: C_1 is more preferred than C_2, $[pref(C_1) > pref(C_2)]$, where C_1 is a new fact that has been introduced by the IF_X. Therefore, ST_1 is fired and its action, A_3, is asserted in the WM. This in turn affects the transition from activity state, A_1 to A_3.

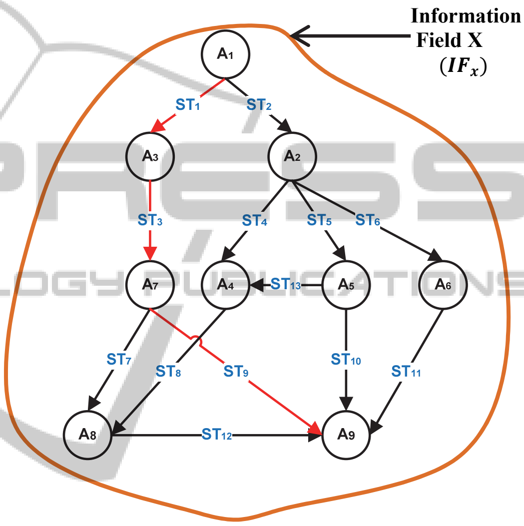


Figure 2: The overlaying of IF_x to IF_0 in the CSTM.

The second iteration (cycle 1) uses this information and the updated facts: C_1, C_2, C_5, C_8 and A_3 would match with ST_3. The rule, ST_3 is then fired and the activity state A_7 is then added in the WM; indicating a transition from activity state, A_3 to A_7. In the third iteration (cycle 2), the RAC again matches the updated facts: C_1, C_2, C_5, C_8 and A_7 in the WM against the rules in the production rule. At this stage, two rules, ST_7 and ST_9 are enabled for firing, and as for now, the conflict set consists of the following information: $\{\langle ST_7, A_7, C_5\rangle, \langle ST_9, A_7, C_8\rangle\}$.

In order to resolve the conflict, a strategy *PreferredOutcome* is applied to select ST_9 for firing because its conditions matches with the preferred outcome. As a result, the rule ST_9 is fired and its action A_9 is asserted into WM, indicating a transition from activity state, A_7 to A_9. Finally, in cycle 3, the execution halts as there are no more rules to fire.

Table 3: Trace of a production system based on the overlapping IF_x and IF_0, where $d(IF_x) = d(IF_0)$.

Cycle	Working Memory			Conflict set	Conflict Resolution	Rule fired
	IF_0	IF_x	derived facts			
0	C_2, C_5	C_1, C_8	A_1 (initial state)	ST_1 ST_2	PreferredCondition	ST_1
1	C_2, C_5	C_1, C_8	A_3	ST_3	NULL	ST_3
2	C_2, C_5	C_1, C_8	A_7	ST_7 ST_9	PreferredOutcome	ST_9
3	C_2, C_5	C_1, C_8	A_9	NULL	NULL	HALT

5.3 The Overlaying of a Dominant IF to Base IF

In the next example (see figure 3), we introduce the information field Y (IF_y), which is more dominant than base information field (IF_0). Note that, the replacement of IF_y, will, thus, bring another set of norms (e.g., facts, rules, preferences) into existing set of norms (see table 4). The overlapping of these IFs may introduce conflicts, which can be further summarised in table 5.

Table 4: Set of norms added from the IF_y.

Types of norms	Norms added from the IF_y
Behavioural norms	$ST_{y1}: A_1 \wedge C_{y1} \rightarrow A_{y1}$ $ST_{y2}: A_{y1} \rightarrow A_6$ $ST_{y3}: A_6 \wedge C_{y2} \rightarrow A_5$
Evaluative norms	$pref(C_{y2}) > pref(C_9)$ $pref(A_9) > pref(A_4)$
Cognitive norms	A_9
Perceptual norms	C_{y1}, C_{y2}

Again, given that A_1 represents the starting activity state, the inference begins with rule, ST_1, and goes on downward until a rule that fires is found. In the first iteration (cycle 0), the RAC matches the current state (conditions): C_2, C_5, C_{y1}, C_{y2} and A_1 in the WM against the ST rules in the production rule. At this stage, a conflict occurs when two rules, ST_2 and ST_{y1} are matched with the current conditions in the WM. Hence, the conflict set consists of the following information: $\{\langle ST_2, A_1, C_2\rangle, \langle ST_{y1}, A_1, C_{y1}\rangle\}$. To resolve a conflict, a strategy *DominantRuleIF* is applied to select a rule from the dominant IF. Therefore, ST_{y1} is fired and its action, A_{y1} is placed in the WM, which in turn moves the activity state from A_1 to A_{y1}. In the second iteration (cycle 1), the RAC again matches the updated facts: C_2, C_5, C_{y1}, C_{y2} and A_{y1} in the WM with the production rule. At this stage, only ST_{y2} matches with the current facts. Hence, ST_{y2} is fired and its action, A_6 is then added into WM, indicating a move from an activity state, A_{y1} to A_6. In the third iteration (cycle 2), ST_{11} and ST_{y3} are matched with the updated facts: C_2, C_5, C_{y1}, C_{y2} and A_6. The conflict set contains the following information: $\{\langle ST_{11}, A_6, C_9\rangle, \langle ST_{y3}, A_6, C_{y2}\rangle\}$. To resolve the conflict, a strategy, *DominantPreferredCondition* is employed to select and fire the ST_{y3} based on the following preferences: C_{y2} is more preferred than C_9, $[pref(C_{y2}) > pref(C_9)]$, which then placed A_5 in the WM. The transition of activity state is now changed from the activity state, A_6 to A_5.

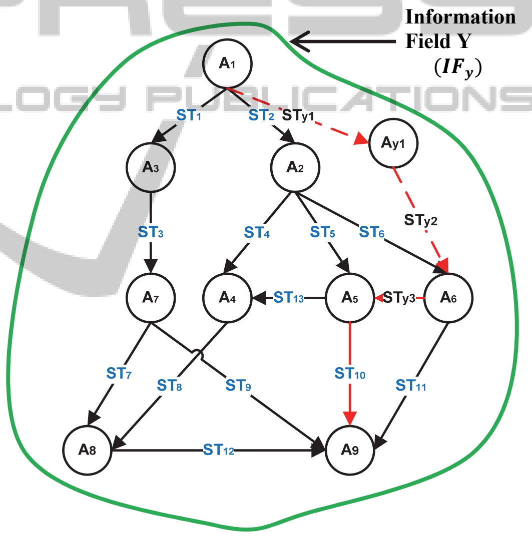


Figure 3: The overlaying of IF_y to IF_0 in the CSTM.

In the next iteration (cycle 3), the RAC again matches the updated facts: C_2, C_5, C_{y1}, C_{y2} and A_5 in the WM against the rules in the production rule.

Two rules: ST_{10} and ST_{13} are matched with the updated facts. Hence, the conflict set contains $\{\langle ST_{10}, A_5\rangle, \langle ST_{13}, A_5, C_7\rangle\}$. To resolve the conflict, a strategy *DominantPreferredOutcome* is implemented to choose ST_{10} as A_9 is more preferred outcome than A_4, $[pref(A_9) > pref(A_4)]$. When the ST_{10} rule is fired, its action, A_9 is added into WM, and the transition of activity state is now changed from the activity state, A_5 to A_9. Finally in cycle 4, the execution halts as there are no more rules to fire.

Table 5: Trace of a production system for CSTM based on the overlapping IF_y and IF_0, where $d(IF_y) > d(IF_0)$.

Cycle	Working Memory			Conflict set	Conflict Resolution	Rule fired
	IF_0	IF_y	derived facts			
0	C_2, C_5	C_{y1}, C_{y2}	A_1 (initial state)	ST_2 ST_{y1}	DominantRuleIF	ST_{y1}
1	C_2, C_5	C_{y1}, C_{y2}	A_{y1}	ST_{y2}	NULL	ST_{y2}
2	C_2, C_5	C_{y1}, C_{y2}	A_6	ST_{11} ST_{y3}	DominantPreferredCondition	ST_{y3}
3	C_2, C_5	C_{y1}, C_{y2}	A_5	ST_{10} ST_{13}	DominantPreferredOutcome	ST_{10}
4	C_2, C_5	C_{y1}, C_{y2}	A_9	NULL	NULL	HALT

6 DISCUSSION AND CONCLUSIONS

We have incorporated norm specifications into production system (PS) model that uses the forward chaining over production rules as a way of reasoning. The concept of information field (IF) provides default context identifier values, and is also capable of systematically capturing different set of norms based on context depending on what type of IF has been added into the Context State Transition Model (CSTM). However, a conflict may occur in a set of shared norms and a strategy is required. In this paper, we presented new strategies, which are capable of handling the preference setting of norms. The selection of strategies is dependent on the situation specification defined in this study. For instance, the implementation of *DominantIF's* strategy is to choose a rule from the dominant IF for firing. However, if the first strategy failed, then another strategy, e.g., *DominantPreferredOutcome* will be selected next. The process of selecting a strategy will continue until one of them matches with the preference setting. The standard strategy will, then, be implemented by the production system (PS) when new strategies fail to resolve a conflict. Besides, these new strategies offer a semantic strategy, which enable the PS to resolve the conflicting norms based on their meaning. While the traditional strategies are only syntactic which resolve the conflicts in accordance to the form and occurrence of rules and conditions. However, the application of strategies in the PS model is limited in terms of user's choices. As such, a user should be able to select their own strategies in resolving the conflicts. Furthermore, in order to make the inference more effective, the random strategy should be considered first, as this strategy is the most selected by other PS. Future work will be focused on the development of multiple scenarios of real-world problems, and then followed by the implementation based on a rule-based expert system, such as the Jess.

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