An Earthquake Response Timing Constraint Workflow Model

Jiangong, Song
State Key Laboratory of Software Development Environment
Beihang University
Beijing, China
sjg@buaa.edu.cn

Qinyong, Li
State Key Laboratory of Software Development Environment
Beihang University
Beijing, China
liqinyong@vip.qq.com

Shilong, Ma
State Key Laboratory of Software Development Environment
Beihang University
Beijing, China
slma@buaa.edu.cn

Jianghua, Lv
State Key Laboratory of Software Development Environment
Beihang University
Beijing, China
jhlv@buaa.edu.cn(Corresponding author)

ABSTRACT

Because of the requirements of earthquake response workflow systems to trustworthiness and time constraints, a workflow model method with time constraints is proposed. There are three views of the model discussed, namely, the resource view, the control view and the time view. The time constraints prediction of resources capability is introduced in the resource view. The equivalent and exception handling mechanism is presented in the control view. The time flow diagram is constructed from the source view and the control view by the time flow graph inference rule in the time view and the real collision detecting and resolving are conducted for both time definition phase and runtime phase. By the relevant research comparison and experiments, the workflow model is able to support the automated detection and resolution for real time constraints conflict.

Keywords

Earthquake response workflow, time constraints, conflict detection and resolution.

1. INTRODUCTION

In recent years, disastrous earthquakes have frequently occurred, that according to the official website of China Earthquake Administration statistics, from January 1, 2007 to May 31, 2016, in the world 197[1] earthquakes occurred of magnitude more than 7, of which most earthquakes to human life and property caused great losses to human life and property. In recent years, more and more earthquake response disposal systems have been applied in the field of disaster response and disposal. Emergency-response workflow model is the key technology for earthquake response and disposal systems. Compared with other workflow models, complexity of the time property in emergency response workflow model is manifested in the following points: (1)Time constraints of the activities in emergency response workflow model include latency, duration, the earliest start time, latest end time, etc. (2)Emergency response disposal belongs to time sensitive business, the time control of the process should be accurate.

Current research on workflow with time restriction[2-6] has no clear description of resource capability and analysis of time constraints. By introducing resources capability time, emergency response workflows carries on reasonable time constraint conflict detection and process adjustment, so as to improve the time accuracy and success rate of the entire business process. In the meantime, current research on time constraint verification and conflict resolution[7,8] focused primarily on time constraint verification, activities schedulability and performance analysis. Reasonable automatic conflict resolution mechanism is not introduced to deal with runtime conflicts. Automatic conflict resolution mechanism will greatly improve the success rate of the workflow as well as the reliability of business processes in emergency response workflow management system.

According to the above problem, this paper proposes a time constraints modelling method to meet these requirements. The method decomposes the time constraints model into three views, namely the resource view, the control view and the time view.

The rest part of the paper is constructed as follows: Section 2 gives a detailed instruction of Emergency-Response Timing Constraint Workflow Net. Section 3 constructs the time flow graph. Section 4 introduces the time constraint conflict detection algorithm. Section 5 introduces the time constraint conflict resolution mechanism. Section 6 conducts experiments and evaluation of ETCWM. Section 7 concludes the paper.

2. EMERGENCY-RESPONSE TIMING CONSTRAINT WORKFLOW MODEL

Definition 1. Emergency-Response Timing Constraint Workflow Net(ETCWN).

ETCWM is defined as seven tuples (P, T, F, M, TC, TA, FC). It satisfies:

(P,T,F) is a model inside the Petri network. P is the library set, T is the transitions set, F is the arc with direction, and $F \subseteq P \times T \cup T \times P$.

$x \in P \cup T$ is one element of the Workflow Net， $\cdot x = \{y|(y \in P \cup T) \wedge (y, x) \in F\}$ is the pre-set for x; $x \cdot = \{y|(y \in P \cup T) \wedge (x, y) \in F\}$ is the rear set for x.

A Petri net is working inside when and only when it meets the following two conditions:1. There are two special libraries, i.e., i and o, library i is a source library: $\cdot i = \emptyset$, library o is a pool library: $o \cdot = \emptyset$; 2. If a transition t^* is added to connect o and i, it makes $\cdot t^* = \{o\}$ and $t^* \cdot = \{i\}$ to get PN^*, then PN^* is strongly connected.

M is a sequence of state of a Workflow Net: $M = (M_0 M_1 M_2 \dots M_n)$, M_i is an m dimensional vector: $M_i = (tp_0, tp_1, tp_2, \dots, tp_m)$, m is the number of elements in P, tp_i is the token in library p_i. Thus, M is an actual execution of a workflow instance, and M_i is the execution state of a workflow instance.

TC is a description of the explicit time constraints demand of emergency disposal, defined as a mapping from the transitions to a time interval $[\alpha, \beta]$, $TC: (T_1, T_2) \rightarrow [\alpha, \beta]$, $T_2 \in T, T_1 \in T \cup \{T_\emptyset\}$, $0 \leq \alpha \leq \beta < \infty$, recorded as $T_1 \prec_\alpha^\beta T_2$, α is the earliest triggering time of T_2 when T_1 is finished, β is the latest triggering time of T_2 when T_1 is finished. If $T_1 = T_\emptyset$, then α is the earliest triggering time of T_2 when T_1 began, β is the latest triggering time of T_2 when T_1 began.

TA is a description of explicit requirements of resource constraints in emergency disposal, a mapping from transitions to a resource model. $TA: T \rightarrow \{RS\}$. RS is a resource model, including staff, supplies, etc.

FC is a mapping from arc to transfer conditions, i.e., Condition, $FC: F \rightarrow Condition$; where Condition is a Boolean expression, which represents the token transfer conditions of an arc.

Transitions can not only be the process main body, but also be a subject in logic relationships, such as conditions determine and branch type judgment, etc.

In the process of time constraint conflict detection, firstly set up rules by time constraint flow graph, construct time constraint flow diagram using the logical relationship and time constraint resource competence model in Resource View. By iterative adaptive adjustment to realize time constraint conflict resolution is shown in Figure 1.

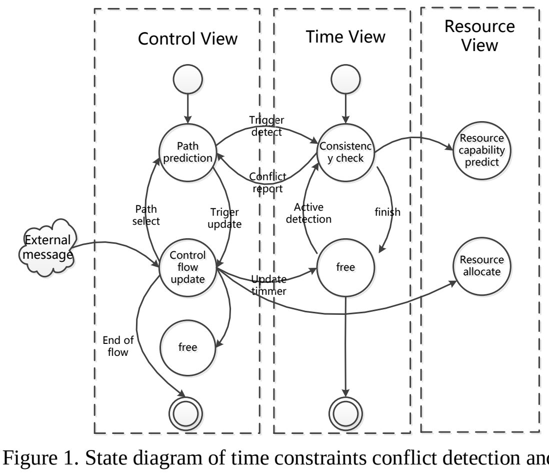

Figure 1. State diagram of time constraints conflict detection and exception handle

3. STRUCTURE AND DEDUCTION OF TIME FLOW GRAPH

Time view represents time constraints information of all activities in workflow instance, including the relations between a sequence of activities, explicitly tasks earliest and latest finishing time, capability time. Time view calculation is done in the Time Flow Graph. All kinds of time constraints information are organized in Time Flow Graph to detect time constraint conflict by time constraint conflict detection algorithm.

Definition 2. Time Flow Graph.

Time Flow Graph is constituted by three tuples: $\Sigma = (P, V, E)$, P is a node t_i which corresponds to the transition. V is the directed edge $v_{i,j} \rightarrow (t_i, t_j)$ between the transitions. E is the time constraint $e_{i,j} \rightarrow t_i \prec_\alpha^\beta t_j$, in which transitions are activated.

Definition 3. Time constraint consistency.

If and only if any constraint $e_{i,j} \rightarrow t_i \prec_\alpha^\beta t_j$ that meets the requirement $\alpha < \beta$ is in time constraints consistency, if not, it is time constraint conflict.

Definition 4. Capability Time.

In a transition t, according to the resource constraint, we forecast the shortest execution time recorded as TET(t) and the longest execution time recorded as TLT(t), TET(t) and TLT(t) are capability times of transition t. Resources capability times meets the requirement of implicit time constraints in emergency disposal workflows.

Rule 1. Structure rule of time flow graph.

1) Dealing with transitions: copy the collection of transitions in ETCWN model and paste into Σ, as $P = T$. Then add $T_\emptyset$ as a starting node to P, as $P = P + \{T_\emptyset\}$.

2) Dealing with explicit time constraints: For any transitions t_i, t_j in ETCWN model, if $\exists TC = (< t_i, t_j >, [\alpha, \beta]) \in TC$, build a directed edge $V' = (t_i, t_j)$ between t_i and t_j,namely $V = V + V'$, then add time constraint $E' = t_i \prec_\alpha^\beta t_j$ to E, namely $E = E + E'$.

3) Dealing with resource capability time: For any transitions t_i, t_j, if there is a library p, $p \in t_i \cdot \wedge p \in \cdot t_j$, build a directed edge $V' = (t_i, t_j)$ between t_i and t_j ,namely $V = V + V'$; according to the resource capability time, we know that after t_i is finished, t_j must be finished $TET(t_j)$ later but in $TLT(t_j)$, namely $E' = t_i \prec_{TET(t_j)}^{TLT(t_j)} t_j$, add E' to E, namely $E = E + E'$.

Rule 2. Extended rule of time constraints derivation

1) Serial structure: Two serial time constraints $t_i \prec_{\alpha_j}^{\beta_j} t_j$, $t_j \prec_{\alpha_k}^{\beta_k} t_k$, can be derived as $t_i \prec_{\alpha_j+\alpha_k}^{\beta_j+\beta_k} t_k$.

2) Parallel structure: Two parallel time constraints $t_i \prec_{\alpha_1}^{\beta_1} t_j$, $t_i \prec_{\alpha_2}^{\beta_2} t_j$, if the relationship is "with", then $t_i \prec_{\max(\alpha_1,\alpha_2)}^{\min(\beta_1,\beta_2)} t_j$; if the relationship is "or", then $t_i \prec_{\min(\alpha_1,\alpha_2)}^{\max(\beta_1,\beta_2)} t_j$.

4. TIME CONSTRAINT CONFLICT DETECTION ALGORITHM

In a workflow with the time constraint, explicit time constraints, process temporal logic and resource capability time may lead to conflict. In order to guarantee the consistency of all kinds of time constraints, in this section we provide time constraint conflict detection algorithm in both definition time and runtime to realize real time constraints conflict detection.

Algorithm 1. Conflict detection algorithm in definition time.

Input: ETCWN=(P,T,F, M,TC,TA,FC)

Output: Boolean, whether the process meets the requirements of time constraints consistency or not.

1) Establish time flow graph in accordance with rule 1.

2) Number the nodes in Σ and initializes the queue Q. Put the starting node t in Q, number t as 1. Cycle out of the queue when Q is not empty, t'=DEQ(Q), put subsequent of t' into the queue in turn , number++. When Q is empty, end the cycle.

3) Check the consistency of time constraint. Mark the starting time of the $T_\emptyset$ as 0, check all the nodes t_j(i=2,…,{V}) in turn： to every precursor $t_i \in \cdot t_j$ of t_j, calculate the cumulative time constraint $e_{i,j} = t_i \prec_{\alpha}^{\beta} t_j$ by parallel rule 2, calculate every time constraint $e_{i,j} = t_i \prec_{\alpha}^{\beta} t_j$ by serial rule 2. If α> β, there is conflict ,end the algorithm; if not, continue to calculate until all the nodes are checked. If there is no conflict, end the algorithm and the time constraint in ETCWN is consistent.

Algorithm 2. Conflict detection algorithm at runtime.

Input: time flow graph in algorithm 1 and the triggering time of all the transitions are already triggered.

Output: Boolean, whether the process meets the requirements of time constraints consistency or not.

Update the time constraints. If both the pre-set and rear set of transitions of constraint are triggered, remove the constraint from the collection. If neither the pre-set nor rear set of transitions of constraint are triggered, leave the constraint unchanged. If the pre-set of transitions is triggered and rear set of transitions is not, to $e_{i,j} \rightarrow t_i \prec_{\alpha}^{\beta} t_j$, calculate the time taken T of the pre-set of transitions, i.e., current time minus pre-set transitions trigger time, $e_{\emptyset,j} \rightarrow t_\emptyset \prec_{\alpha-T}^{\beta-T} t_j$. For the time constraints generated by 3) in Rule 1, recalculate the resource capability time and update.

5. AUTOMATIC CONFLICT RESOLUTION MECHANISM

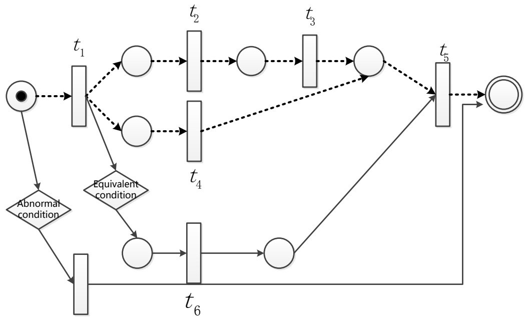

Figure 2. The flow chart with equivalent structure and exception handle structure

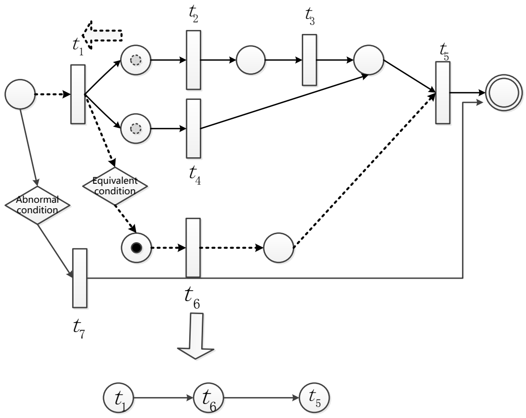

Figure 3. The flow chart of go back and select the new path

To support time constraints automatic conflict resolution, this section proposes a constraint violation handling mechanism based on equivalent replacement. The concept of equivalent structure and exception handling structure are introduced to realize automatic conflict resolution. Equivalent activity can replace the original activity when the original activity failed to perform or conflict. Exception handling activities are based on the equivalent activity to record abnormal warning, if equivalent activity still failed to perform or conflict, then execute exception handling activities. The time flow graph is shown in Figure2. Dotted line represents the normal activities in work flow.

If it comes across time constraint conflict at t_5, go back to t_1 and perform the equivalent activity, the process is shown in Figure.3. Dotted lines represent the checking and perform of the equivalent activity.

6. TIME-CONSTRAINTED CONFLICT DETECTION AND RESOLUTION EXPERIMENT

Firstly, we randomly selected a workflow that has no conflict resolution, it meets the time constraints in define time but time constraint conflict could occur at run time. Run the workflow for 1000 times, record number of successful executed workflow as N. Secondly, we add the conflict resolution mechanism in Sections 4 and 5. Run the workflow for 1000 times again, record successful executed workflow number as M, the equivalent substitution routing number as M1, exception handling path selection number as M2.

Finally, repeat the experiment for 100 times to get the average result. The results are shown in Table 1.

Table 1. Conflict resolution experiment results

Experiment	Success	failure	Success rate
With conflict resolution	979	21	97.9%
Without conflict resolution	863	137	86.3%

In the workflow with conflict resolution mechanism, equivalent activities perform 83 times while exception handling activities perform 33 times. It can be concluded from the experimental results that the equivalent replacement and the exception handling mechanism, as a supplement for possible runtime time constraints, have significantly improved the success rate of workflow execution.

The experimental results shows that ETCWM can dynamically evaluate the runtime time constraint conflict in workflow provide automatic conflict resolution which greatly improves the success rate of emergency-response workflow.

7. CONCLUSIONS

This paper proposes a time-constrained modelling method to meet the requirements for high reliability, high time accuracy and complicated time constraints in earthquake emergency response workflow systems. On the basis of this model, the time constraints flow diagram is built, conflict detection and resolution algorithm is derived. The method decomposes the time constraints model into three views, i.e., the resource view, the control view and the time view. By the relevant comparison and experiment evaluation, the model is proved to be able to support the automatic detection and resolution for time constraints conflict at runtime, and improve the time accuracy and success rate of the process execution, which provides strong support for earthquake emergency response and disposal.

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