Workflow-based Modeling of Web Application and Automatically Generating Test Sequences*

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Abstract—Web applications are main applications in Internet. Before developing Web Application, a CPN (Colored Petri net) model based on workflow is constructed. By this way, the rationality of the workflow can be ensured before developing, rather than the irrationality is found during testing phases. The constructed CPN model is analyzed with CPN tools. Moreover, AGTS tool is implemented to generate test sequences and it is also suitable for all CPN models. To prove the method’s efficiency, the make-order business process of logistics management system is used as an example to construct CPN model that is based on workflow, and then verify the correction of the constructed CPN model. At the same time, AGTS tool can automatically generate the test sequences of the constructed CPN model and its usability of this automatic tool is demonstrated.

Keywords—CPN; model; workflow; automatic; test sequence

I. INTRODUCTION

Web applications have had a significant impact on all aspects of our lives and works. As more and more businesses being conducted through the web, the quality assurance of web applications have become more and more important. Due to the randomness and the heavy workload of the developing and testing of Web applications, it is necessary to improve the efficiency of developing and testing of Web applications, which is a premise to ensure the software quality and reliability. In this paper, we proposed to construct models for Web applications before developing and testing. The proposed process is shown in Fig 1.

Fig. 1. Develop and test process based on business process

An efficient method is proposed to construct a CPN(Colored pet net) model based on workflow before the developing of web applications. It is helpful to ensure the rationality of the workflow of Web Applications before developing. Moreover, constructing a formal model before developing also can help us achieve the test sequences. These test sequences are useful in testing phases. In addition, an automatic tool was implemented with java language and it traversed -.xml file that was achieved by CPN Tools to generate test sequences.

The remainder of the paper is organized as follows: Section II is the related work. Section III simply introduces the concepts of Petri net, CPN, the hierarchical modeling and the analysis of WF-net. AGTS tool is designed and introduced in Section IV; Section V presents the make-order business process of the logistics management system as an example to describe how to construct a model, how to analyze the model and how to automatically generate test sequences; Section VI introduces the conclusion and the research work in the future.

II. RELATED WORK

Web applications are sophisticated and interactive programs and used to implement highly interactive applications which also have high quality requirements. To analyze and test these web applications for increasing the quality present many challenges. Formal method is a useful method to specify and verify web applications by applying techniques form mathematics and logic. Petri net is a formal method as well as a graphical appealing language that has formal semantics and easy-to-understand graphical feature. It offers formalized and visualized methods as well as some analysis techniques. Therefore, Petri net was widely studied and applied in modeling for workflow. Workflow models are widely used for specifying business processes of Web applications[1-3]. Li Jianjun[2] introduced some obvious advantages for workflow modeling based on Petri nets by compared with four workflow modeling method. Research efforts for workflow modeling based on Petri net have produced many theoretically results. W.M.P.VAN[4] discussed the use of Petri nets in the context of workflow management, and the powerful analysis techniques which can be used to verify the validity and correctness of workflow. All these existing studies have shown that Petri
net is applicable for modeling, however, most of them separate the modeling from the developing and testing of Web applications.

III. WORKFLOW BASED ON PETRI NET

A. Introduction of Petri net, CPN and CPN Tools

Petri net is a formal method which is suitable for modeling and analysis of concurrent, asynchronous, or distributed systems[5-6]. In Petri net, place denotes a state; transition denotes an activity. A transition and a place is connected via directed arcs.

CPN(Colored Petri net) is a discrete-event modeling language combining Petri net with standard ML and it also can solve the problems which is easily appeared in basic Petri net, such as state space explosion[9]. Especially it is more suitable for modeling complex systems[10]. Therefore, in this paper, we choose CPN as the modeling language.

CPN Tools[11] is a tool which is used to edit, simulate and analyze CPN models. It can generate a useful state space report to analyze some of the dynamic properties of models, such as reachability, liveness and so on.

B. Basic structure of Workflow based on Petri net

Definition 1(WF-NET)[8,9]: A model constructed for a workflow by Petri net is called WorkFlow net (WF-net).

There are four basic types in Petri net that are also suitable for WF-net, such as sequential, parallel, conditional, and iteration[8].

1) Sequential structure: Shown in Fig.2, which is used to deal with causal relationships between tasks. It means transition B can not execute until transition A finishes its execution.

(2) Parallel structure: Shown in Fig.3. It means that after the completion of transition A, the execute order of transition B and C is arbitrary. It includes two building blocks: AND-split and AND-join.

(3) Conditional structure: Shown in Fig.4. It means a choice is made between transition A and D, and only one of these two transitions will be enabled by place P. Conditional structure has two building blocks in order to model a choice between two of more alternatives: OR-split and OR-join.

C. Hierarchical Modeling of CPN

In a hierarchical model, it is possible to relate a substitution transition to a separate subpage. A subpage provides a more detailed description of the process that is represented by the transition. Hierarchical model makes the structure of the model more clearly and easier to understand, as well as reduce the difficulty of model analysis when a complex and large scale model is encountered.

D. Analysis of WF-net

A WF-net is a specific Petri net, so many analysis methods of Petri net are still applied on WF-net[8]. In this paper, we utilize the definition of WF-net which was introduced in [8] to analyze model reliability: (1) Increasing a transition t between Place i and o (i is initial state and o is terminative state), then w is a strong connectivity Petri-net. (2) Each place and transition belongs to path from i to o. (3) No existing deadlock in model.

In accordance with WF-net definition, the model is reliable, however, it may has logic errors. Zhou Fuming[14] presented an algorithm to check the correctness of the WF-net. It was proved that if there was no deadlock and dead transitions, the model was reasonable. Therefore, we analyze the CPN model not only by WF-net definition, but also by some properties of Petri net to verify its rationality and safeness.

IV. TEST SEQUENCE GENERATION TOOL

This section introduces an implemented tool to generate test sequences automatically. A desired coverage of test sequences is achieved. The reachability graph of CPN model can be modeled as a directed graph, in which each node represents a reachable state and each arc corresponds to a transition condition. According to the properties of the reachability graph, Cordemans P[12] defined three criteria that is respectively: state coverage, arc coverage and path coverage.

In this paper, we choose state coverage and arc coverage as the coverage criteria that means all states and arcs in the reachability graph of CPN model should be covered at least once.

AGTS tool is implemented to automatically generate test sequences and explore the reachability graph of CPN model by a strategy to guarantee coverage with respect to state coverage and arc coverage. The pseudo-code in Fig.6 illustrates the main blocks of the algorithm of AGTS tool. AGTS tool reads the -.xml files achieved by CPN Tools, and then analyzes the file to explore the reachability graph to generate test sequences and some information about coverage.
AGTS tool displays some information on the graphical interface such as test sequences, total number of states and arcs, covered number of states and arcs and the coverage. The information is helpful to give testers some indices of the degree of Web applications testing.

V. EXAMPLE

The logistics management system is designed to make users post items faster and more convenient. The make-order business process is the core business of this system. To demonstrate the usability and the efficiency of AGTS tool, we take the make-order business process as an example in this paper. In order to describe the modeling process more clearly, the flowchart of order business is shown in Fig. 7.

A. CPN Models of Order Business

For the flowchart of make-order business in Fig.7, hierarchical CPN model is used to construct the model. The constructed model is composed of three CPN pages: topPage(in Fig.8), login(in Fig.9) and order (in Fig.10). (topPage is the top-level of the constructed model, login is a further refinement of the login transition of topPage, and order is to further refine the order transition of topPage).

B. Analysis of the Constructed Model

Combined with the analysis of WF-net in section III, utilizing WF-net definition and some properties of Petri net, such as reachability, liveness and boundedness to analyze the WF-net. Beside some formal analysis method, the advantages of CPN can be seen through simulation by CPN Tools. It can simulate the execution of workflow to find logic errors, as well as provide the state space report and reachability graph, through which we can get some useful information to analyze properties of Petri net. The reachability graph of the constructed model is shown in Fig.11 and the state space report is shown in table 1.

![Flowchart of make-order business business](image_url)

![TopPage of make-order business model](image_url)

![Login subpage of make-order business model](image_url)

![Order subpage of make-order business model](image_url)

![State Space Report of Make-Order](image_url)

<table>
<thead>
<tr>
<th></th>
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<tr>
<td>Scc Graph</td>
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<th>Dead Markings</th>
<th>Home Markings [13]</th>
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<table>
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<table>
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<tr>
<th>Token's name</th>
<th>max</th>
<th>min</th>
</tr>
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<tbody>
<tr>
<td>Order fail order</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Order failPaid</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Order filled</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Order list</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Order orderPage</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Order reject</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>logIn name</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>logIn passwordWrong</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>logIn reject</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>logIn register</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>logIn registerSuccess</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

| topPage | 2   | 0   |
| topPage hasName | 1   | 0   |
| topPage hasOrder | 1   | 0   |
| topPage home | 1   | 0   |
| topPage in | 1   | 0   |
| topPage openFail | 1   | 0   |
| topPage out | 1   | 0   |
| topPage payFail | 1   | 0   |
| topPage payPage | 1   | 0   |
| topPage paySuc | 1   | 0   |
| topPage start | 1   | 0   |
AND FUTURE WORK

desired coverage criteria. The coverage of test sequences achieves 100% and reaches the coverage criteria is state coverage and arc coverage. The chosen test sequences are achieved by the AGTS tools. The total number of states and arcs, covered number of states and arcs as well as state and arc coverage.

C. Generate Test Sequences

During the test phase, test sequences can be automatically generate by AGTS tool. The input of AGTS tool is the -.xml file that is achieved by CPN model. Through analyze the -.xml file of the above model by the AGTS tool, some information can be achieved that is shown in Fig.12, such as test sequences, total number of states and arcs, covered number of states and arcs as well as state and arc coverage.

VI. CONCLUSION AND FUTURE WORK

Most internet services are offered by web application. To improve the quality and efficiency of the developing and testing of Web applications, this paper proposes a method to model for Web applications based on workflow before the developing and testing. WF-net is applied to construct model and CPN Tool is used as modeling tool.

Moreover, AGTS tool is implemented for automatically generating test sequences through analyzing -.xml file of the CPN model. Further, the make-order business process of logistics management system is used as an example to describe the modeling of CPN and model validation, and then AGTS tool is applied to generate test sequences, and the coverage and the total number of states and arcs are obtained. The AGTS tool is suitable for all CPN models to generate test sequences.

The future research work includes the following two aspects. One is how to optimize the length of test sequences automatically, and the other is how many workflows we should model for one web application and their collaboration. In a web application, there are many workflows, how to choose the workflows to model and their collaboration is a key point.

REFERENCES


