

A Simulation Based Approach for Rationality Verification of Test Sequence for CTCS-3 Train Control System

Zhang Yong^{1, a}, Han Jingqiang^{2, b}

^{1,2}School of Electronic and Information Engineering, Beijing Jiaotong University, Beijing 100044, China.

^azhangy@bjtu.edu.cn, ^b13120239@bjtu.edu.cn

Keywords: CTCS-3 Train control system; Test sequence; Train operation simulation; Rule base; Rationality verification; Verification strategy

Abstract. A CTCS-3 train control system is the key equipment for guaranteeing the safety, reliability and efficiency of high speed railway. Test sequence is the important document to guide the testing for train control system. Manual preparation of test sequence is characteristic of low efficiency and high demand for professional expertise, so it is difficult to guarantee the rationality of test sequence. This paper proposes a simulation based approach for rationality verification of test sequence. Firstly through analyzing the generation process of test sequence, the rationality criteria are obtained; secondly a rule base is built to store the rules used to verifying the rationality of test sequence; finally a train operation simulation environment is established for verifying the rationality of test sequence. Several key issues such as rationality criteria, rationality rules, rules base, and verification strategy are addressed.

Introduction

CTCS-3 train control system is the key equipment that ensures the safety, reliability and high efficiency of train operation. Before putting the system into service, it is necessary to carry out a series of testing including laboratory testing, pilot line testing, integrated testing and commissioning, as well as interoperability testing. To ensure the safety and orderliness of a field testing, a set of test sequences must be prepared by concatenating the test cases [1-2].

Some research related to the generation of test sequence has been carried out. Various methods have been proposed, such as the methods based on Chinese Postman algorithm[3-4], formal method[5], expert system[6], rule inference[7], state matching[8] and case-based reasoning[9]. A computer-aided tool[10] has been developed with the aim to providing an integrated graphical editing environment, with such function as automatic generation of test sequence files in customized WORD format for field testing and XML test scripts for laboratory simulation platform, and electronic management of test cases, test sub- sequences and test sequences.

This paper focuses on the rationality of the test sequence on the basis of rationality requirement, constructs the rules base for rationality verification, and proposes the test sequence rationality verification method bases on train operation simulation.

This paper is organized as follows. Firstly, the criteria for test sequence rationality is defined; secondly the simulation method for train operation is introduced. Thirdly, the rule base for the verification is introduced; fourthly, the verification process and verification strategy are elaborated; finally, some conclusions are drawn and some future works are envisaged.

Test Sequence Rationality

Terminology

(1) Feature and Test Case [1-2]

A feature is a group of requirements in System Requirements Specification for CTCS-3 Train Control System (v1.0) (SRS) [1], which can be tested on the available standard interfaces of the system.

A test case is for one test of a feature, which contains: ①basic information of the test case, including the number, the description of the test case, the applicable operating modes and application levels, the test target, the test method and test constraints; ②start/end conditions, including the state of the internal variables and the interfaces before/after the execution of the test case; ③step-by-step description of the test procedure. In each step, the input/output data on the interfaces are specified.

(2) Test Sequence

The field testing of a train control system is a comprehensive project, which involves not only the operation of the whole train control system, but also the co-operation of other railway sectors including rolling stock, power supply, permanent way, transportation organization and so on. It consumes not only a lot of manpower, material and financial resources, but also has potential safety hazards. In order to ensure the safety and orderliness of a field testing, it is necessary to prepare a set of test sequences according to the test conditions and requirements.

A test sequence document shall at least contains: ①identity information of the test sequence, such as the number of the test sequence, the major functional points to be tested; ② the test prerequisites, including the start position of the train, and the initial state of the on-board equipment; ③ the track layout graph, which is used to illustrate the overview track layout of the test line, the train path, the test conditions (such as track occupation, Temporary Speed Restriction (TSR)) and some prompt boxes for the focus points during a test trip;④the test procedures, which describe step by step the status of the train, the change of operating mode of the onboard equipment, the test conditions, the related cases and the expected test results.

Criteria for Test Sequence Rationality

The rationality of test sequence rationality shall be reflected in the following aspects:

(1) Completeness

The set of test sequences shall cover all the test cases to be tested. Additionally, the track conditions needed by some of the test cases shall be included in the test sequence.

(2) Continuity

A test sequence is formed by concatenating the test cases according to the start and end condition of each test case. The end mode of the former test case should be same as the start mode of the latter test case.

(3) Correctness

Considering that there are some special locations on the line, for example, RBC/RBC border, Neutral zone, it is necessary to ensure various constraints for the special locations shall be met. And the concatenation of test cases shall comply with the working process of the on-board equipment.

(4) Feasibility

In a field testing, due to the limitation of the actual conditions, various constraints related with special time and location, special equipment and special status shall be taken into consideration. In addition, test conditions shall be arranged at convenient places and the test scenarios shall be achievable.

(5) Efficiency

Under the premise of guaranteeing the completeness, continuity, correctness and feasibility, the consumption of test resources including test time, test manpower and material resources shall be kept as minimum as possible.

Test Sequence Verification Software

The test sequence verification software is shown as in Fig.1.

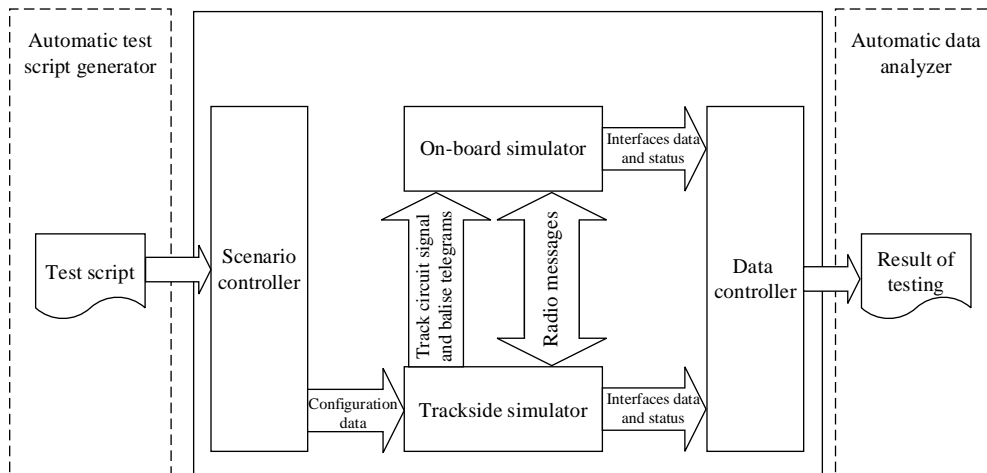


Fig. 1 Architecture of Test Sequence Verification Software

The software consists of four functional modules: scenario controller, on-board simulator, trackside simulator, and data collector. The scenario controller is in charge of controlling the testing process; the on-board simulator is responsible for simulating train motion dynamics and the function of on-board equipment; the trackside simulator sends the necessary trackside information to the on-board simulator; the data collector gathers all the data produced during the testing process.

The input of the software is the test scripts generated according to the test sequence. The main window of the software is shown as in Fig.2.

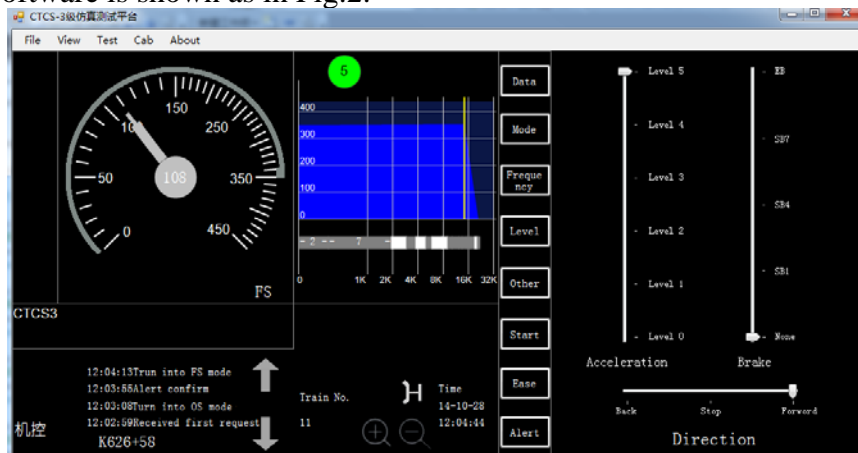


Fig. 2 Main Window of the Test Sequence Verification

Rationality Verification of Test Sequence bases on Train Operation Simulation

The rationality verification of test sequence bases on train operation simulation is to import test sequence into the train operation simulation environment and to simulate train operation. The state of train operation will be displayed on the DMI, when abnormal situation appears, the test sequence contents will be compared with the rationality rules stored in the rule base through the comparison module, and finally the test sequence rationality verification results will be obtained.

The construction of rule base

(1) Knowledge acquisition

The rule base stores the rule used to verify the test sequence rationality. The knowledge source includes expertise of domain experts, all kinds of specifications related with train control system, test data, cases study and the related database. The process for knowledge acquisition is shown as in Fig.3.

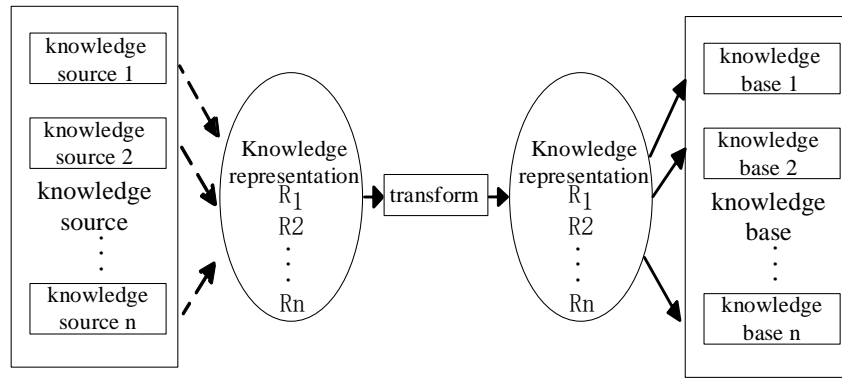


Fig. 3 Process of knowledge acquisition

(2) Knowledge arrangement

In this paper, we use knowledge tree to organize and express the knowledge which contains not only the rationality requirement of test sequence, but also the user action and test conditions.

For example, the knowledge tree for transition to FS mode is shown as in the Fig.4.

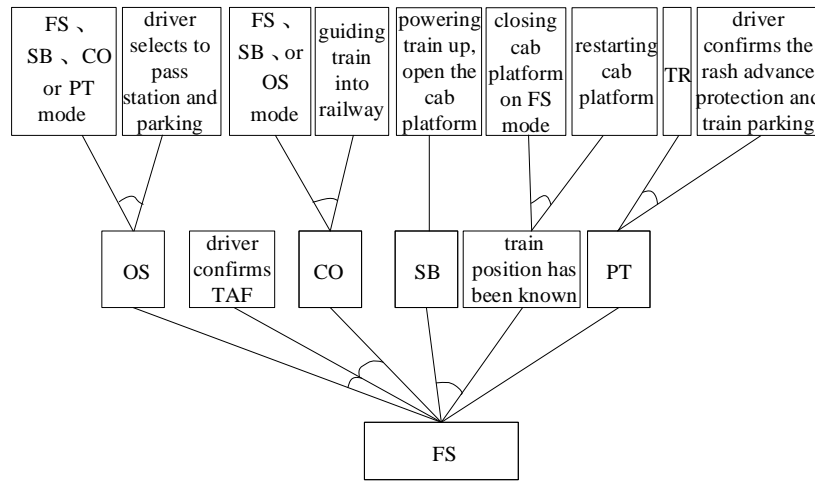


Fig. 4 Knowledge tree for transition to FS mode

The knowledge tree for switching to Post Trip Mode is shown as in Fig.5.

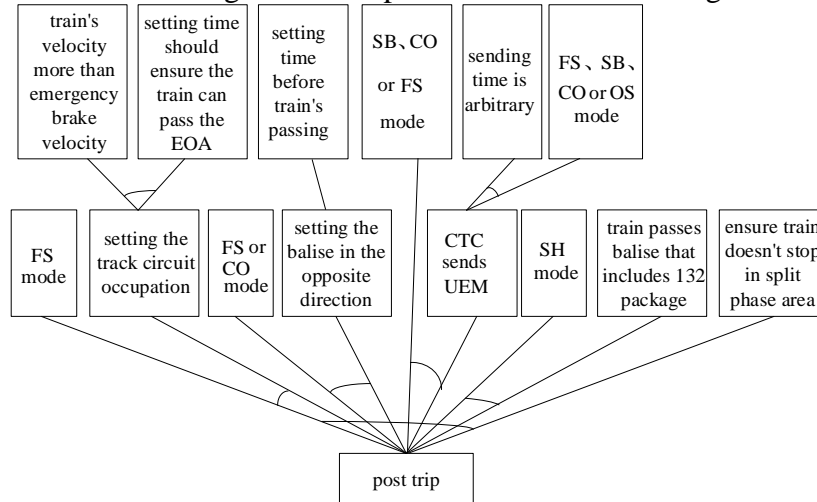


Fig. 5 The knowledge tree for transition to Post Trip Mode

(3) Rules design

The naming standard for the following rules: **Rule_rule contents_number**.

For example, **Rule_Mode_1**: is mode switch rules 1; **Rule_Func_1**: is the rules 1 of function point test.

Table 1 Mode Transition Rule 1

Rule Name	Rule Content	
Rule_Mode_1:	IF	SH mode to SB mode
	Then the Conditions	(driver selects "exit shunt mode") AND (train parking) OR (closed cab platform)

Table 2 Train Mode Change Rule 2

Rule Name	Rule Content	
	IF	test function point is SB mode to OS mode
Rule_Mode_2:	Then the Conditions	(driver selects "override") AND (train parking)

(4) Rules presentation

The first-order predicate representation is used to express the rules.

The rule in table 1 can be expressed as:

Rule_Mode_1: ModeChange(SH, SB) \rightarrow (DriverSelect (SH) \wedge Equal(Speed,0)) \vee Status(DriverDest, Closed);

The rules in table 2 can be expressed as:

Rule_Mode_2: ModeChange(SB, OS) \rightarrow (DriverSelect (Override) \wedge Equal(Speed,0));

Process of Rationality Verification of Test Sequence

Firstly, setting up train data including train type, train length, ATP (Automatic train protection system) start mode, train start position and train stop position.

Secondly, selecting the test line and planning route, and importing the test sequence into the train operation simulation environment.

Thirdly, starting the train operation simulation environment and verifying the rationality of test sequence.

Finally, viewing the results of rationality verification of test sequence, and exporting rationality verification of test sequence report.

The process is shown as in Fig.6.

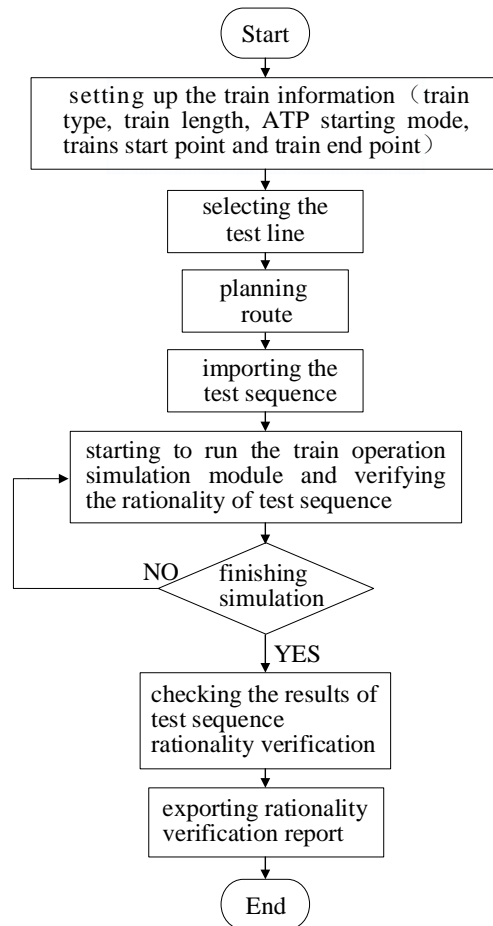


Fig. 6 Process of rationality verification of test sequence bases on the simulation

In the process of train operation simulation, if the train operation is normal, there will be no warning displaying on the DMI; if the train can't operate normally because of the unreasonable test sequence, the exception handling will be triggered, to compare the test sequence contents with the test sequence rationality rules stored in the rule base, and recording the unreasonable points of the test sequence.. The process of rationality verification is shown as in Fig.7.

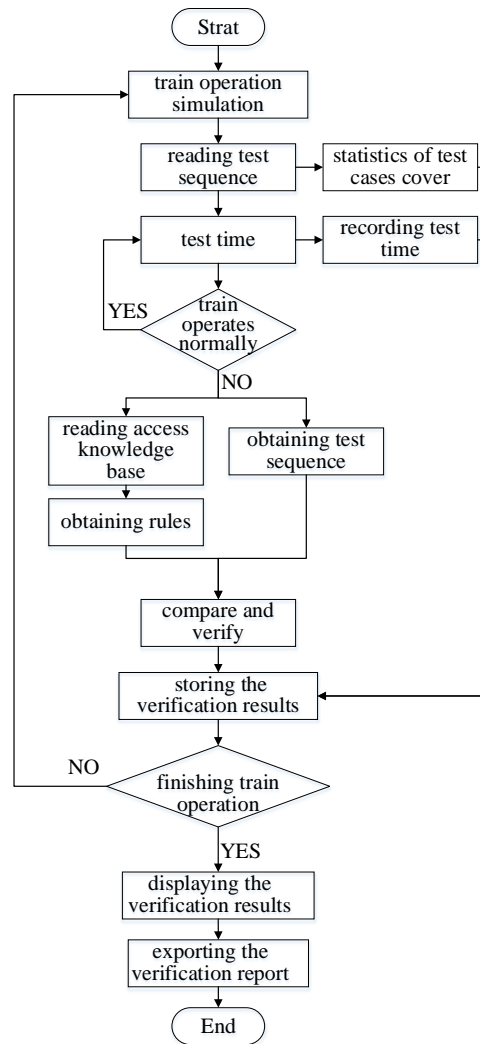


Fig. 7 Process test sequence rationality verification

Design of Verification Strategy

A method based on multi-threaded queue for comparing test sequence with rationality rules is proposed.

When a train operates in abnormal situation, the contents of the test sequence will be pushed into the queue to form a contrast queue, at the same time, the rule acquisition thread, will search for related rules stored in rule base to form a rules queue according to the keyword in the contrast queue. Between the two queues there is a comparison thread.

The comparison thread compares the contents of the rules queue with that of the contrast queue, if the contents is the same, the dequeuing operation of the two queues will continue until the problem is found.

In order to improve the efficiency, avoid deadlock and ensure the safety of the thread, in the process of implementation, it is necessary to add a head lock and a tail lock to the queue, and make the queue contain at least one node.

The relationship between queues and threads is shown as in Fig.8.

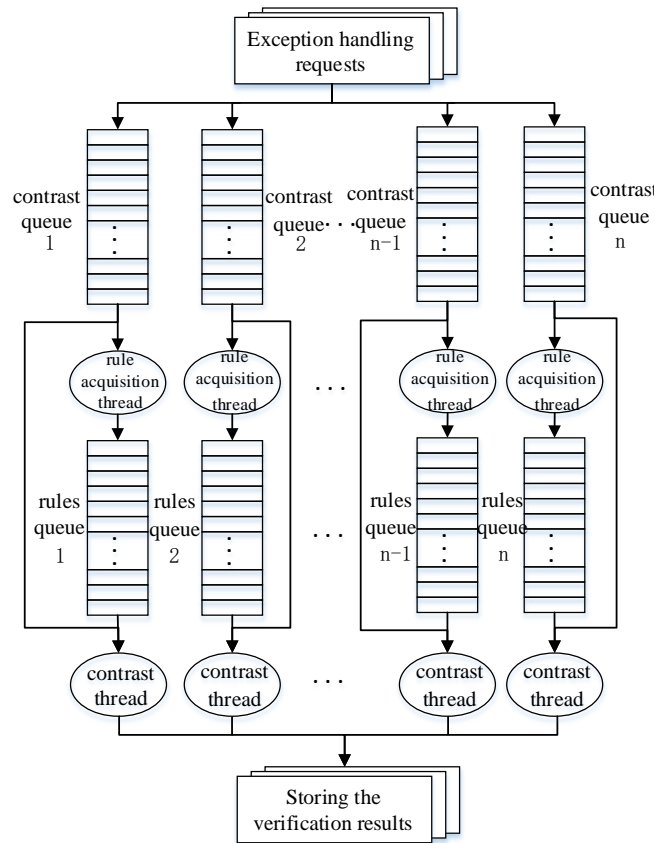


Fig. 8 Relationship between queues and threads in the process of rationality verification

Conclusion and Future Works

A simulation based on approach for rationality verification of test sequence for CTCS-3 train control system is proposed. A test sequence verification software is developed and a rule base is built to store the rationality rules. A method based on multi-threaded queue for comparing test sequence with the rationality rules is proposed. Future works include the study on stability of train operation simulation environment and optimization of verification strategy.

Acknowledgement

This work was supported in part by the Nature Science Foundation under Grant 61490705.

References

- [1] Transportation Bureau of MOR, "System Requirements Specification for CTCS-3 Train Control System (v1.0)," Beijing: China Railway Press, Beijing, 2009.
- [2] Transportation Bureau of MOR, "Test Cases for CTCS-3 Train Control System (v3.0)," Beijing: China Railway Publishing House, 2009.
- [3] LI Wei, WANG Haifeng, CTCS-3 Train Control System On-board Equipment Test Sequence Optimization, Journal of Beijing Jiaotong University, Vol.34, No.2, pp.75-78. 2010, in Chinese.
- [4] ZHANG Yong, WANG Chaoqi. The method for the optimal generation of test sequence for CTCS-3 on-board equipment [J]. China Railway Science, Vol.32, No.3, 2011, pp.98-106.
- [5] ZHAO Xianqiong, ZHENG Wei, TANG Tao. Model-based Formal Approach for Generating Test Cases and Test Sequences Automatically by Example of the ETCS-2. Journal of the China Railway Society, Vol.34, No.5, pp.70-80, 2012. in Chinese.

- [6] Zhang Yong, Sha Shuo, Wang Shu, “An Expert System Approach for Generating Test Sequence for CTCS-3 Train Control System”, 2013 Fourth International Conference on Intelligent Control and Information Processing (ICICIP), Jun. 2013, pp. 271-276.
- [7] Zhang Yong, Han Yuan, Wu Jianxiong. A Rule Inference Based Method for Generating Test Sequence for CTCS-3 Train Control System [Z]. 2014 7th International Conference on Information Management, Innovation Management, and Industrial Engineering, 2014.
- [8] Yong Zhang, Yuchen Xie and Xiaokun Zhang. Study on the Method for Automatic Generation of Test Sequence for Train Control System Based on State Matching [Z]. 2014 International Conference on Computer Science and Artificial Intelligence.
- [9] Shu Yue, Zhang Yong, Research on Test Sequence Generation for CTCS-3 Train Control System Based on Case-Based Reasoning. Railway Computer Application, vol.23, no.6, June 2014, pp. 16-20.
- [10] ZHANG Yong, WANG Shu, ZHANG Xiaokun, SHA Shuo, XU Gaozhen. A Computer-aided Tool for Generating Test Sequences for CTCS-3 Train Control System [J], Advances in Information Sciences and Service Sciences(AISS),v4, no11, 2012, pp.311-319.