The assignment of trains at a station

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Signed declaration

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ABSTRACT

The train is one of the most historical and popular transportation modes around the world. As the development of Technical Economy, a city train's railway layout became more complicated, which resulted in a series of problems. And how to solve these problems with optimal scheduling becomes a serious question.

The assignment of optimal scheduling of trains in a station aims to find the most sensible method to deal with the negative situations and bring the system back to normal operation by using the Expert System.

Keywords: Expert System.

Preface

First of all, I would like to thank my supervisor Dr. Joab Winkler, he gave me lots of help when I doing this project. He encouraged me and helped me to solve problems. And I am very grateful to Lei Yang, she gave me great support in life and in spirit. Also, I would like to thank me parents and families, they always give me motivate to move on.

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CHAPTER 1: INTRODUCTION

1.1 Background

The train is one of the most traditional and modern modes of transportation around the world. Since the development of Technique and Economy, city railway layouts have been more complicated and a series of simultaneous problems has followed. "How to solve troubles with optimal scheduling" has become a serious question.

Under normal operations, the trains in the urban rail transit system operate in strict accordance with a plan. But because of the existence of random interference factors, the train operations will inevitably deviate from the plan. On the urban rail transit system, the deviation of a single train tends to spread to other trains, and sometimes even to the magnitude of the impact. When the train is running in a severe disruptive state, the entire system's operating efficiency is significantly reduced. You need to adjust the overall range of chaos that has been running first, so that you can bring the system back to normal operation as soon as possible.

1.2 Aims and objectives

This project's aim is to find an optimal scheduling of trains in a station.

Description of this railway station:

1. The station has four platforms, which means there are four tracks in this station.
2. There are ten platforms in this station, platform 1 is short platforms, and the rest are long.
3. Platforms 1-4 have one track.
4. There are several situations that may happen at the train station.

Description of trains in this station:

1. There are 93 trains that will stop or bypass this railway station.
2. There are three kinds of trains: Long Train/ Short Train/Major City Train.
3. Each train has its arriving/departure direction.
4. Each train has its scheduled time on the plan (arriving/departure).
5. Short trains come every 30 minutes.
6. Long trains come every 40 minutes.
7. Major city trains arrival an hour a time.
8. Each train may not arrive on time because of a few minutes deviation.

Constraints:

1. Short trains can use both long and short platforms, while long trains can only stop at long platforms.
2. For all the trains on the same track, the next train's direction of arrival should be same as former train's direction of departure as much as possible.

So, the question how to find optimal trains scheduling is how can get a method to satisfy these limitations and to solve problems reasonably. This project's aim is to try to develop a methodology that meets all the constraints and minimizes the losses caused by disruptions and deviations.

1.3 The Dissertation Structure

Chapter 1 - Introduction

This chapter introduces the background of this project, and explain its aims and requirements.

Chapter 2 – Conceptual Overview

This part of the report introduces the background and history of the optimal scheduling of trains and some approaches that have been used to find the best method. Then, this report will explain the Expert System and how it works.

Chapter 3 – Requirements and Analysis

The project's functional requirements are listed and analysed in this chapter. In addition, this chapter also analyses the basic elements: trains, tracks, and a proposed text plan.

Chapter 4 – Design

In this section, I describe the project, explain how to build the rule-based Expert System step by step, and elaborate the reasoning method.

Chapter 5 – Coding and testing

This chapter explains how to write the program for this project, and discusses how to formulate the testing rules and results outputs.

Chapter 6 – Results and discussion

The results of the project are presented and discussed in this section and opportunities for further work are identified.

Chapter 7 – Conclusions

This last chapter summarizes this project’s report and conclusions.

CHAPTER 2: CONCEPTUAL REVIEW

This section will introduce the theme of this project, the basic elements of this subject, and the research methods to find the optimal scheduling of trains in the rail way station scenario.

2.1 Background of optimal scheduling of trains in railway station

A train transport system is very complex. The standard operation of the train runs in strict accordance with the train plan. But because there are many random factors of inference, the train will inevitably deviate from the proposed operation. Usually, a train will be late to the station and bring some loss of time, which can even affect the next train, so a new scheduling strategy is necessary.

Train schedule design is a critical element of the overall railroad operating plan design problem. [1] The proposed schedule design will encompass train routing, train timing, and connections to satisfy the limitations and cope with novel situations.

Traditional train operations use a manual adjustment method, which requires a dispatcher, who must have a certain degree of experience and business acumen. However, the quality of dispatchers is uneven, and the significant amount of manual work makes the task of adjusting the program difficult to perfect.

As a result, the poorly performing scheduling methods that dispatchers use in practice have a direct impact on the quality of service offered to the passengers, and the negative effects of disruptions on the regularity of railway traffic may last for hours after the end of the disruption (Kecman et al., 2013).

While the real-time adjustment of train operations can ensure the operational efficiency of the system, the use of an intelligent automatic adjustment method can overcome the traditional resistance to change whereby the shortcomings of manual dispatching will be replaced with timely and comprehensive development of automated optimal adjustments. Therefore, it is necessary to study the history of how the operation of the urban rail transit train has adapted over time. [2]

2.2 History of optimal scheduling of trains

In 1972, with Szpicgel proposing the issue of “Optimal Train scheduling on a Single Track Railway”, the view that exists an ‘optimal train schedule’ has been put forward (Szpicgel, 1972). Since then, scholars have researched how to find the optimal train schedule.

2.2.1 Method based on traditional mathematical programming

At the earliest, Szpicgel, and Jovanovic proposed some methods for adjusting the railway transport system based on the branch and bound method for the single-track/ double-track railway to reduce the overall delay cost and consumption respectively (Szpicgel, 1972; Jovanovic et al., 1990). In 1994, Cao Jiaming published an article and proposing that linear programming is the most appropriate algorithm for the task, he combined it with the structure of the model to discuss the feasibility of dual algorithms (Jiaming, 1994). But they were still unable to meet the real-time requirement because the traditional mathematical programming method could not efficiently solve the problem of train operation adjustment with a sufficiently fast calculation speed.

2.2.2 Method based on discrete event dynamic system theory

In addition to using traditional mathematical methods, many scholars have used the theory of discrete event dynamic systems to find a solution to the optimal train scheduling problem. Xiaoming Xu, in an article published in 2015, proposed a new rearrangement method, known as the efficient train rearrangement strategy (ETRS), based on the discrete event model (Xu, 2015). Due to the high efficiency of the discrete event model, ETRS can rearrange more trains in a relatively brief period. Moreover, if the duration of the event increases, all performance standards increase evenly.

2.2.3 Method based on simulation analysis

In 1995, Norio introduced a new simulation method of train traffic rescheduling combining the PERT (Program Evaluation and Review Technique) method with a knowledge-based approach. In this approach, PERT calculates the arriving/departure time of trains, and the parallel knowledge-based program does the rescheduling. By using this method, a practical railway transport rearrangement system can be set up. The system also passed their testing.

2.2.4 Methods based on Artificial Intelligence

It is not easy to develop optimised schedules to meet business needs as well as operational and market constraints. However, with the development of artificial intelligence, and the use of AI technology such as constraint programming, Expert Systems, genetic algorithms, and other methods to intelligently generate matching target requirements, optimisation timetables can meet the rules and limitations.

In 1988, Cheng Yu proposed the Expert System's view. The Expert System uses the train sequence setting method to determine the rules. In the algorithm, various judging conditions are realised as expert knowledge, and the production rules are used to collect the composition.

2.2.5 Method based on Genetic Algorithm

The genetic algorithm is a computational model for simulating the natural selection and genetic mechanism of Darwin's theory of biological evolution. It is a method of simulating the optimal solution of the natural evolutionary process.

In 2015, Rahul Barman et al. proposed a fixed path and genetic algorithm composed of a heuristic model, based on an optimised train scheduling method.

2.3 The Expert System

This project used the Expert System which is based on Artificial Intelligence and Computer Technology as the methods to find the optimal scheduling of trains at in the station scenario.

The Expert System is a smart computer program system, which contains many experts in the field of knowledge and experience; this system can use the knowledge of human experts and solve the problem. In the artificial intelligence area, the Expert System has always been the hottest field. [7] More than 50 years of development have occurred since the first Expert System (Dendral, 1965) appeared at Stanford University. In that time, the system has been applied in every field.

2.3.1 Brief introduction of the Expert System

The Expert System is defined as the use of a computer model of a human expert's reasoning to solve compound problems (that require an expert interpretation in the real world) and draws the same conclusion as the expert. [8] In short, the Expert System has two parts: a knowledge base and an inference engine (as shown in Figure 1). A knowledge base is an empirical set of knowledge and experience, and the inference engine is the reasoning ability mapping on a computer built on the knowledge base. How to build a reasonable knowledge base and inference engine is the most complicated part.

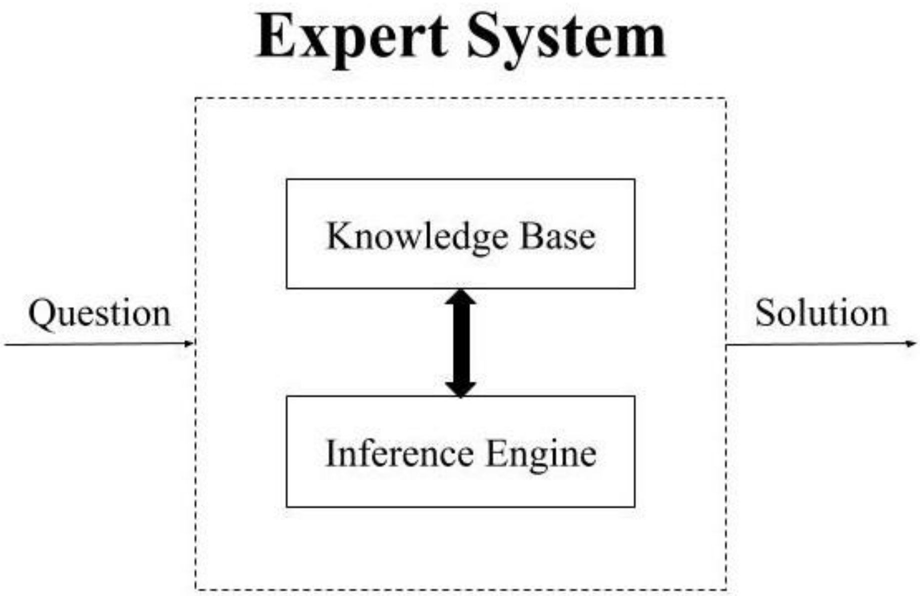

Figure 1. Simple Expert System

There are 5 phases during the development history of an Expert System.

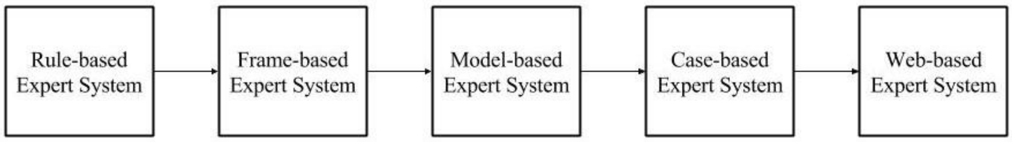

Figure 2. Development History of an Expert System

2.3.2 The Development history of Expert System

Rule-based Expert System

There are two ways to draft the rule based reasoning (RBR) for an Expert System.

Rules from experts:
This method is based on a human expert's experiences, classified it into rules and reasoning through enlightening empirical knowledge. Because this approach has a premise and clear results, RBR is the most common way to build an Expert System. The DENDRAL Expert System, the MYCN Expert System, and PROSPECTOR Expert System are examples of RBRs.

RBRs directly imitate the psychological process of humanity using "IF" "THEN" and some other words to represent a human’s reasoning process. We can split them into three categories: 1. non-attribute; 2. list-attribute; and 3. digital attribute.

Rules from algorithms:
Unlike rules from experts which need discussion, have limitations, and foster inefficiency, rules from algorithms can generate rules automatically from data. For example, the ID3, C4.5, and C5 algorithms were based on the Gini index's CART Algorithm.

Frame-based Expert System

In 1975, Minsky pointed out how to use "Frame" to describe the data structure. The framework contains the name, knowledge, and slot for a concept, which when an instance of the concept is encountered, the relevant specific value of the case is then entered into the framework. The frame-based Expert Systems can be regarded as a natural extension of a rule-based Expert System, although it is an entirely different programming style. [9]

The frame-based expert system	Frame	Example	State of knowledge	Process knowledge	Groove
Object - oriented programming techniques	Class	Object	Properties	Event	Attribute type, constraint range...

Table 1. The Equivalent Concept

Once Minsky introduced the framework concept into the programming language field, object-oriented programming techniques came into being. The corresponding terms are shown in Table 1.

The most prominent feature of frame representation is that it is good at expressing structural knowledge and has great inheritance and naturality. Therefore, this system is suitable for things with fixed format, such as moving goods and incidents.

Case Based Expert System

Case Based Reasoning (CBR), is a case-based Expert System. Figure 3 shows the progress of this system. By searching for similar problems that have already been solved successfully, and understanding the differences between the new and the already resolved problems, their backgrounds, and other differences, a CBR can reuse or refer to the previous solutions and information to achieve the final novel solution to a new problem. When a CBR cannot find a similar case, it uses this case as a new case in the system. It was first proposed by American scholar Roger Schank (Research on Dynamic Storage Model of Human Learning and Memory) in 1982. The first case-based Expert System in the true sense is the CYRUS system, developed by Professor Janet Kolodner from the Yale University in 1983. This system is based on Schank's dynamic storage model and problem solving Memory Organized Packet (MOP) theory.

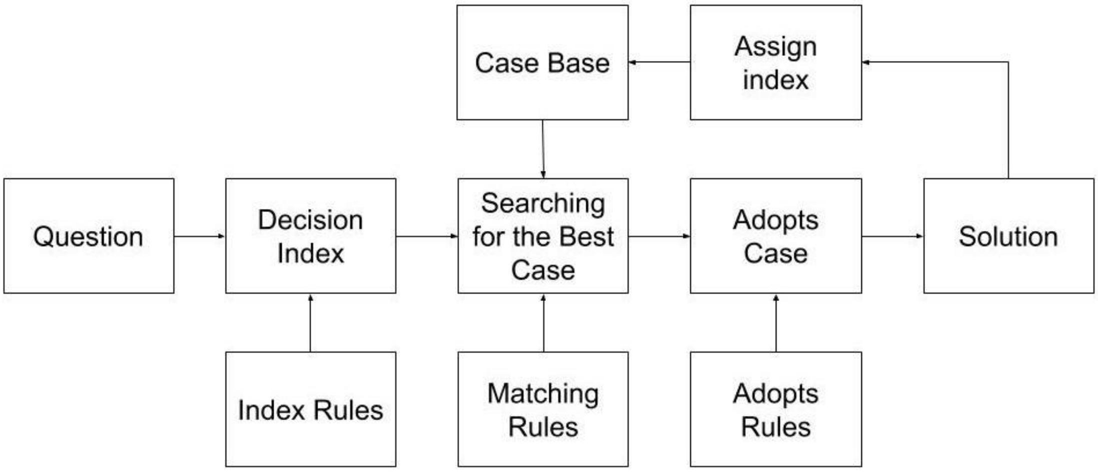

Figure 3. Progress of the Case-based Expert System

Model-based Expert System

The traditional Expert System's main weakness is that it is lacking knowledge reusability and sharing. Using ontology (Model) to design an Expert System can solve these shortcomings. It can increase system functionality, improve performance, and improve independent and in-depth research and various models and their related results for the system design. [13]

The ontology-based Expert System supports the reusability and sharing of the system through three aspects: the definition of the meta-model, the conceptualisation of design principles and the standardisation of the knowledge base. By strictly defining the model, principle, and knowledge base of a thing, it is possible to ensure that the thing is strictly aligned with the model. In a future design, the model can be easily recalled speeding up the system design. [14]

There are two new branches developed by the ontology-based Expert System. One is the causal time model, which takes the causal time scale into the model. Another is the neural network model, where the network is used to realize the reasoning of knowledge.

Causal Time Model:

Causality is very significant for the behaviour that human beings understand of a physical system. Human recognition of causality is based on the time delay between cause and result.

Neural network model:

The neural network model is substantially different from the traditional production Expert System. [15] Firstly, the knowledge representation changes from explicit to implicit; secondly, knowledge is not acquired by human processing but is automatically received by an operator [16]; and finally, the inference mechanism is not the traditional inductive reasoning, but instead is the weights in the competition layer [17].

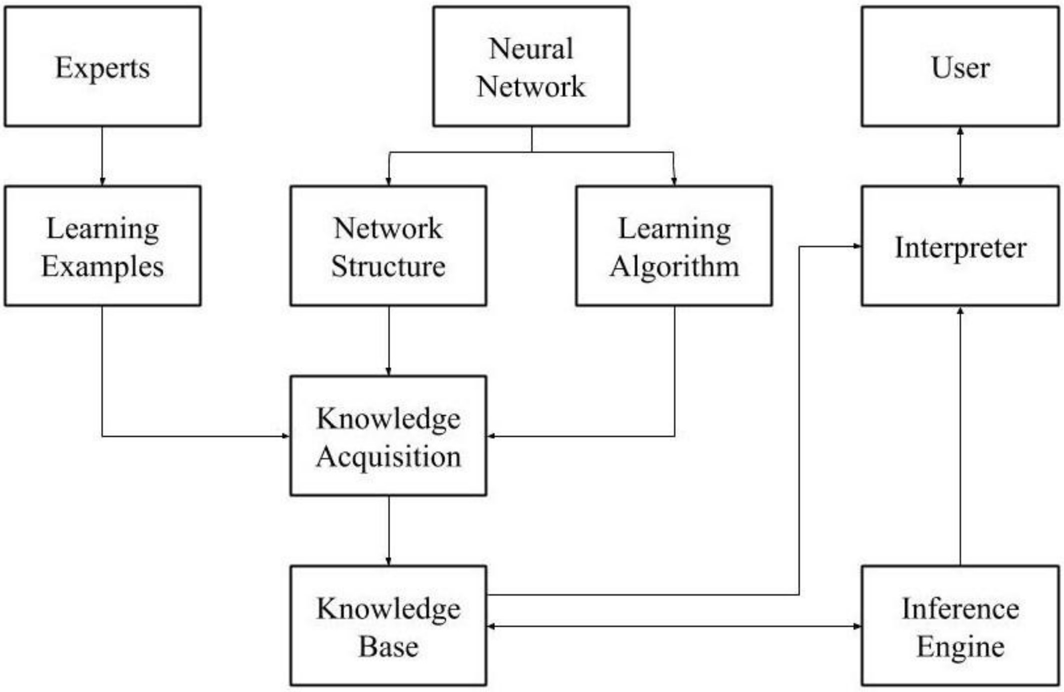

Figure 4. Integrated Graph of Neural Network Expert System

Compared with the traditional generative Expert System, the neural network has the following six advantages [18]: 1. inherent parallelism; 2. distributed associative memory; 3. good fault tolerance; 4. adaptive ability; 5. learning ability through examples; and 6. convenient for hardware implementation.

2.3.3 The Analysis of Expert System

There are no necessary algorithms to solve the problems of an Expert System, and they usually make inferences under imprecise, uncertain, or incomplete information, and then finally, draw a conclusion. The Expert System is the application of an artificial intelligence technology and a computer technology —reasoning and judgment— and a simulation of human experts to solve problems and make decisions. Its originality is that it can solve those difficult but previously only-solvable-by-human experts types of complex problem [20][21].

2.3.4 The Structure of Expert System

The structure of the Expert System is in the construction approaches and organisation forms for each component. While in practice, when using different Expert Systems, due to various application fields and goals, is often necessary to adopt different system structures. In each particular circumstance, one can adjust the simplified fabric of the Expert System: simplify, refine, delete, or increase some parts. The basic structures of the Expert System consist of the following parts:

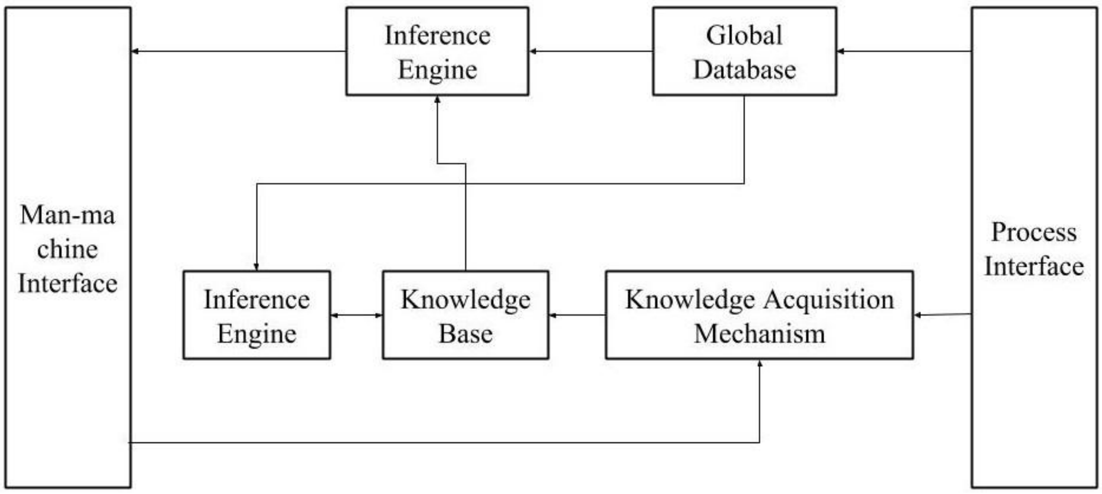

Figure 5. The Simplify Structure of Expert System

1. Knowledge Base

The knowledge base is the core component of the Expert System. A broad range of reality, feasible operations and rules, etc. are used for access and managing the expert knowledge which is needed for solving problems, Through the knowledge base management system, the functions of knowledge base access, retrieval, editing, modification, knowledge updating and maintenance can be realised. The quantity and quality of knowledge contained in a knowledge base determine the ability of an Expert System to a great extent.

The construction of a knowledge base can be divided into two parts: knowledge acquisition and knowledge representation. The knowledge acquisition problem to solve is how to get there from the field expert's knowledge. The knowledge representation challenge is to express expert knowledge acquired and stored in the knowledge base to resolving the problem of how to use it in a form that the computer can understand.

2. Global Data Base

The global database is also called an integrated database or a database for short. It is a collection of symbols or data in the process of problem-solving, also known as working memory. It is used to store the original data needed for solving the problem and the intermediate information (data) derived from the reasoning process, including the initial information, the inference of the central hypothesis, the conclusion of the inference, and the information about the thinking process. Therefore, the facts in the database can, and often do, change.

3. Inference Machine

The inference engine is the organisation control mechanism of the Expert System. And in the field of Artificial Intelligence, it applies logical precepts to the knowledge base to infer additional information. Under its control and management, the entire Expert System can function in a coordinated manner in a logical manner.

According to the user's input data, the inference machine can make use of the knowledge in the knowledge base, and according to the current state of the database, and the present condition of the database, it can solve the problem according to a similar expert level: Analyse, judge, decide, introduce new conclusions or facts, or operate.

An important feature of an Expert System is that the inference engine program should align with the Expert System's reasoning progress but have nothing to do with the structure and composition of the knowledge base. That is, the inference engine and the knowledge base are separate. Which refers to the advantage of an Expert System: there is no need to change the inference engine while it is possible to modify and extend the knowledge base.

4. Interpretation Mechanism

The interpretation mechanism is responsible for explaining and interpreting the process of solution. It answers questions from customers and enabling users to understand the reasoning process and the knowledge and data it uses to do so. During its operations, the interpretation mechanism usually uses the knowledge from the knowledge base (the middle result of a database reasoning process), the intermediate hypothesis, and the record, etc. The transparency of an Expert System depends on the performance of the interpretation mechanism. The interpretation mechanism has become an important output channel for real-time Expert Systems such as fault diagnosis, generation, and operation guidance.

5. Knowledge Acquisition Mechanism

The knowledge acquisition mechanism is responsible for building, modifying, and expanding the knowledge base, as well as maintaining the consistency and integrity of the knowledge base. Knowledge acquisition mechanisms have the means to change the knowledge, and they can modify the content of dialogue with experts into the internal knowledge of knowledge base. They can update the original knowledge in the knowledge base and increase new insights.

6. Interface.

The interface is the information transmission link between a user and the system and it provides a friendly interactive environment for users to use the Expert System. It can complete the two-way data conversion from user to Expert System and from Expert System to the user. It can also support the dialogue between them as well. Users can input data, ask questions, understand the reasoning process, and review the thinking results. The system can answer the user's questions and explain them through the human-machine interface. The multimedia human computer interface is now the most efficient form.

2.3.5 The characteristics of the Expert System

The basic design concept of the Expert System is to use the computer program to replace the manual data identification and analysis, to achieve a reasonable plan for the train operations within the station. The Expert System is a knowledge system. As an intelligent system, it summarizes the relevant knowledge summed up by the human experts into the system, simulates the human thinking mode, and establishes the appropriate reasoning principles. The key features of the Expert System are: enlightenment, transparency, flexibility, and uncertainty reasoning.

1. Enlightenment

The problem for the Expert System is often unreasonable, and the problem solving knowledge not only includes theoretical knowledge and common sense, but also includes the experts own inspired knowledge. This heuristic knowledge may be incomplete and inaccurate, but can be applied to analysis and reasoning to solve complex or difficult problems. In the process of solving the problem, an Expert System’s application and combination of inspired knowledge (or even a variety of experience) imitate the expert's thinking and cognitive processing. Therefore, the Expert System is instructive and can be efficient and accurately reason, judge, decide and conclude.

2. Transparency

The Expert System can explain its own reasoning process and answer the questions which are raised by the user so that the user can understand the reasoning process and increase their trust in the Expert System. When the Expert System interprets the user's question, it will use the knowledge from the knowledge base and the intermediate result of the problem-solving process. This interpretation mechanism provides a transparent interface for the Expert System. Therefore, the user can easily accept the Expert System. In addition, the rationality of the knowledge that have been used in the process of problem solving can be verified by reviewing the reasoning path of the examination Expert System. When the solution to the problem is unsatisfactory, the knowledge engineers and users can discover the failure in reasoning and get some experience to improve the system.

3. Flexibility

The flexibility of the Expert System refers to its ability to expand and enrich the knowledge base, as well as to improve the system performance, becoming a state of self-learning. Because the knowledge base and the inference machine in the

Expert System are independent, the knowledge represented in the knowledge base is obvious. Therefore, the expansion and revision of the Expert System knowledge base is more flexible and convenient. In this way, the Expert System can always continue to add new knowledge, as well as modify and update the original knowledge. After the establishment of the Expert System, the inference machine can select the relevant knowledge from the knowledge base, and construct the problem-solving sequence according to the characteristics of the problem. The ability of the inference machine is an aspect of the flexibility of the Expert System. This feature means the Expert System has a very wide range of applications.

4. Uncertainty reasoning

The methods that the expert used to solve some problems are empirical. The empirical knowledge is used to solve the problem of imprecision and the existence of certain probabilities. In addition, the information provided by the relevant questions is often uncertain. The Expert System can comprehensively apply fuzzy and uncertain information and knowledge to reason.

The Expert Systems offers a mechanism for setting up the institutional or corporate knowledge of the system. That is the Expert System can store or document knowledge so that the knowledge and experience would not be lost even individuals are not in the firm anymore (Liebowitz, 1995).

2.4 Programming method

2.4.1 Brief introduction of Java

Java is an object-oriented programming language, which not only absorbed the advantages of the C++ language, but also avoided some of the aspects that made the C++ difficult to understand, such as multiple inheritances, the pointer concept. As a result, the Java language is powerful and easy to use. As a representative of a static object-oriented programming language, Java implements object-oriented theory very well and allows programmers to perform complex programming in an elegant manner.

2.4.2 Why choosing Java

Java has the characteristics of simplicity, object orientation, distributed, robust, secure, platform independence and portability, multi thread, dynamic and so on. Due to this, Java is suitable for this project. Because the railway transport system is not that complicated, the rules are not complex, and it is not too hard to use Java as the program language in this scenario.

CHAPTER 3: REQUIREMENTS AND ANALYSIS

3.1 Project Requirements

This project simulates how a railway station functions. Assuming there is a train station which has various tracks and some of them are long platforms and some of them are short. In common operation, many trains will stop and bypass this station. Due to the fact that there are various tracks, a short train can stop at both long and short tracks while the long train can only stop at a long platform. Each train has unique arriving direction and departure direction and different properties. Additionally, there are random inferences that may influence this railway transport system's normal operations, like train delays. In this project, we will create a method to figure out what is the optimal scheduling of trains in this station model, to manage the trains and make adjustments to put this system back on track when it falters.

3.2 Project Analysis

This project "Optimal Scheduling of Trains at a Station" can be divided into four sections: Train, Track, Inference Factors, and The Schedule. The scheduling refers to the Railway System Adjustment, that when congestion occurs during the trains operation, this scheduling brings it back to an orderly state.

In this project, the Train and the Track are the essential elements with several properties. The railway transport system in this project is a 'trains and tracks' question. When the entire system is running smoothly, the basic event is matching trains with tracks, so they have some common attributes like length and directions. And both the train and track have their own conditions, for example. Trains must wait for an empty track and the track is not suitable for trains which travel in different directions. Also, there are several train types which may cause different situations.

For trains, they run strictly by the plan. Each train arrives at the railway station and has an arrival time and arrival direction. The train needs an appropriate platform, and then once it has completed the stop it leaves in the departure direction. Then, for the tracks, when the train arrives, the system distributes the most appropriate train into each platform (track), which gives new attributes to the tracks (e.g. full or empty) and records it into the system. In the simple terms, the behaviour of the train changes the property of the track.

There are several random Inference Factors that can impact the railway transport system. In this project, there are also some uncertain factors to influence the normal operation. For example, adding a random number causes the train to arrive at the station too early or late. When two trains use the same track, there will be a train waiting for the space, which will result in delays to the train, so that the train deviates from the regular train plan.

This section is divided into two types of Schedules. The first schedule is a basic time table which is related to trains. The second schedule is a real-time schedule. When an emergency occurs, the units (train) in the train system do not operate according to the schedule. The system is restored to normal operation through a system adjustment.

3.3 Test Plan

This project's testing is divided into two parts:

1. *Output of specific event.*

When an emergency occurs, it will output to the console followed with solutions, which can show how this system works during the railway transport system running in this project.

2. *Output of whole system's condition.*

This project designed an evaluation criterion that, when an accident occurs, gives a value that represents the extent to which the current schedule deviates from the original timetable. Then this project evaluates the system by looking at the table for the original and actual schedules.

Chapter 4: Design

Based on the third chapter, the design steps will be discussed in this section. First, lay down the basic schedule (timetable) and all the parameters; second, choosing the method and selecting implementation methods and programming languages, software, and finally building the rules, algorithms, and the Expert Systems.

4.1 Parameter Formulation

4.1.1 Basic Schedule

Train name	Train length	Train arriving Time	Train stay time	Train arriving direction	Train departure direction	Train type
Short Train	SHORT	04:00	10	EAST	EAST	Short Train
Long Train	LONG	04:00	10	WEST	WEST	Long Train
Major City Train	LONG	04:00	20	EAST	EAST	Major City Train
Short Train	SHORT	04:30	10	EAST	EAST	Short Train
Long Train	LONG	04:40	10	WEST	WEST	Long Train
Short Train	SHORT	05:00	10	EAST	EAST	Short Train
Major City Train	LONG	05:00	20	EAST	EAST	Major City Train
Long Train	LONG	05:20	10	WEST	WEST	Long Train
Short Train	SHORT	05:30	10	EAST	EAST	Short Train
Short Train	SHORT	06:00	10	EAST	EAST	Short Train
Long Train	LONG	06:00	10	WEST	WEST	Long Train
Major City Train	LONG	06:00	20	EAST	EAST	Major City Train
Short Train	SHORT	06:30	10	EAST	EAST	Short Train
Long Train	LONG	06:40	10	WEST	WEST	Long Train
Short Train	SHORT	07:00	10	EAST	EAST	Short Train
Major City Train	LONG	07:00	20	EAST	EAST	Major City Train
Long Train	LONG	07:20	10	WEST	WEST	Long Train
Short Train	SHORT	07:30	10	EAST	EAST	Short Train
Short Train	SHORT	08:00	10	EAST	EAST	Short Train

Long Train	LONG	08:00	10	WEST	WEST	Long Train
Major City Train	LONG	08:00	20	EAST	EAST	Major City Train
Short Train	SHORT	08:30	10	EAST	EAST	Short Train
Long Train	LONG	08:40	10	WEST	WEST	Long Train
Short Train	SHORT	09:00	10	EAST	EAST	Short Train
Major City Train	LONG	09:00	20	EAST	EAST	Major City Train
Long Train	LONG	09:20	10	WEST	WEST	Long Train
Short Train	SHORT	09:30	10	EAST	EAST	Short Train
Short Train	SHORT	10:00	10	EAST	EAST	Short Train
Long Train	LONG	10:00	10	WEST	WEST	Long Train
Major City Train	LONG	10:00	20	EAST	EAST	Major City Train
Short Train	SHORT	10:30	10	EAST	EAST	Short Train
Long Train	LONG	10:40	10	WEST	WEST	Long Train
Short Train	SHORT	11:00	10	EAST	EAST	Short Train
Major City Train	LONG	11:00	20	EAST	EAST	Major City Train
Long Train	LONG	11:20	10	WEST	WEST	Long Train
Short Train	SHORT	11:30	10	EAST	EAST	Short Train
Short Train	SHORT	12:00	10	EAST	EAST	Short Train
Long Train	LONG	12:00	10	WEST	WEST	Long Train
Major City Train	LONG	12:00	20	EAST	EAST	Major City Train

Table 4.1 Part of the basic schedule

At the beginning of this part, formulating the basic schedule (timetable) is necessary. In this basic schedule, there are some significant properties that should be defined: 1. Train name; 2. Train length; 3. Train arriving time; 4. Train stay time; 5. Train arriving direction; 6. Train departure direction; 7. Train type.

4.1.2 The railway station

The station is the main scene of this project. It consists of platforms (tracks). There are also limitations for this part, and some parameters should be defined.

Description of trains in this station:

1. There are 93 trains that will stop or bypass this railway station.
2. There are three kinds of trains: Long Train/ Short Train/Major City Train.
3. Each train has its arriving/departure direction.
4. Each train has its scheduled time on the plan (arriving/departure).
5. Short trains come every 30 minutes.
6. Long trains come every 40 minutes.
7. Major city trains arrival an hour a time.
8. Each train may not arrive on time because of a few minutes deviation.

The platform has the following attributes: 1. Platform Number; 2. Platform length; 3. Platform direction (the previous train’s departure direction); 4. Platform status.

4.1.3 Trains

Description of trains in this station:

1. There are 93 trains that will stop or bypass this railway station.
2. There are three kinds of trains: Long Train/ Short Train/Major City Train.
3. Each train has its arriving/departure direction.
4. Each train has its scheduled time on the plan (arriving/departure).
5. Short trains come every 30 minutes.
6. Long trains come every 40 minutes.
7. Major city trains arrival an hour a time.
8. Each train may not arrive on time because of a few minutes deviation.

4.1.4 Constrains

Constraints:

1. Short trains can use both long and short platforms, while long trains can only stop at long platforms.

2. Each platform (track) can only using by one train to stay/bypass.
3. For all trains on the same track, the next train’s direction of arrival should be same as former train’s direction of departure, as much as possible.

4.2 Method Choosing

Based on Chapter 2: 2.2 “History of Optimal Scheduling of Trains”, there are several approaches that have been used to research how to find the optimal schedule of trains. 1. the method based on traditional mathematical programming/discrete event dynamic system theory/simulation analysis/ artificial intelligence/genetic algorithm and 2. the Expert System.

The railway transport system is a complex system. It is hard to find the optimal scheduling of trains in a limited time by using a method based on traditional mathematical programming. Because of the complexity of the discrete event dynamic system and the difficulty of the simulation analysis, the method based on the artificial intelligence seems to be the better approach.

Due to the heuristic, transparency, and flexibility of the Expert System, this method might be a better way.

4.3 The Expert System design

According to the analysis of this project, the rule-based Expert System is the most appropriate way to find optimal scheduling of trains in a station.

4.3.1 Knowledge base

The first step of using a rule-based Expert System is to define the knowledge base. And it contains two sections: knowledge acquisition and knowledge representation.

Knowledge acquisition

In this project, the producer gets the expert's knowledge and experiences from the internet, the common sense of life, and railway station's information in real life. The most important task is to make sense, to find solutions that are reasonable. If there are some problems or the decision does not make sense, the user can make changes to adjust.

Knowledge representation

This is the most significant part of this method. According to 4.1, data is separated into several parts: the train and the track (platform). The table shows the attributes of these two elements.

Train's Attributes	Name	Length	Arriving Time	Departure Time	Stay Time	Arriving Direction	Departure Direction	Type
Platform's Attributes	Number	Length	Arriving Time	Departure Time	Occurred Time	Direction		

Table 4.2 Train's attributes and platform's attributes

It is worth noting that this project adds a property called "status" to trains and tracks (platform). This "status" property is the key parameter in the knowledge representation that train's status has five basic conditions, and platform has three.

Train status:

0: The train has not arrived yet.

1: The train already entered the station.

2: The train is waiting for an empty platform;

3: The train is waiting to enter the station.

4: The train is going through the station.

5: The train is already leaving.

Platform's status:

0: The platform is available.

1: The platform has been occupied.

Through these two variables, it is easy to observe the situations between trains and platforms. Coupled with the previously mentioned train and rail attributes, the clear majority of the situations can be identified by the system and entered into the knowledge base.

4.3.2 Global database

In this project, the global database will be implemented by Java programming.

4.3.3 Inference Engine

This section should design the rules for this rule-based Expert System. While it is clear how to get the situation in this train transport system from the knowledge base and the global database, just how to deal with those situations will be designed in the inference engine.

S1: When multiple trains are going to use the same track.
The priority of trains is: major city train> the long train> the short train> the freight train. This is because that the major city train is the largest train with the lowest frequency, and the most passengers. Because the short train has more options to choose, the long train has higher priority than the short train. In addition, trains should wait five minutes for the previous train pass the track. Furthermore, for the priority of platforms, the smaller the number, the more priority.

S2: When the train enters the station.
The major city trains and long trains are both long, and the short train is short. Because the short train can stay at both the long and short platforms, and the long train can only use the long track, when the length of the train is short, it uses the short platform first.

S3: When the train is waiting for an empty platform.

When a train is waiting on a vacant platform, the waiting time of the train currently standing on the platform should appropriately reduce. Because of the longer the delay, it means that the difference between the arrival time and the schedule indicates that the train system is operating with a deviation.

S4: When there is a certain range of time, there is a train of the same type passing through/staying at the station.
When the system is faced with such problems, the Expert System will organise the train bypass the station. This method reduces the additional parking of the train, thus saving resources and lessens the burden on the train system.

S5: When the train arrives earlier.
When the train arrives at the railway station early than the scheduled time, the Expert System will appropriately extend the time that the train stops at the station. Except in the situation that a train needs to wait for platform and it is already late.

S6: When the train arrives late
The system will also adjust this situation by changing the time that the train stops at the railway station. If the train is too late, it is necessary to make a quick rush. The train may be called directly through the station to recover the schedule as soon as possible.

4.4 The train operation adjustment function design

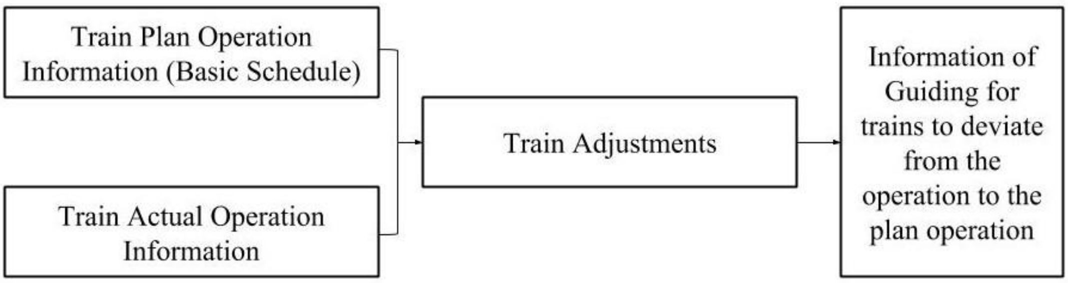

Figure 4.1 IPO

The train operation adjustment module adjusts the train operation to ensure it is normally operating according to the running diagram.

This rule-based Expert System's adjustment is done automatically. This means that the system of automatic data collection appropriately triggers the train service data correction. The change results fit through the calculation system, operational data is adjusting the train departure from the program, running the map as soon as possible to return to normal driving, or to minimise the deviation. The complete process has no manual participation and is implemented independently by the system.

4.5 Processing flow of trains

4.5.1 The train arrival related processing flow

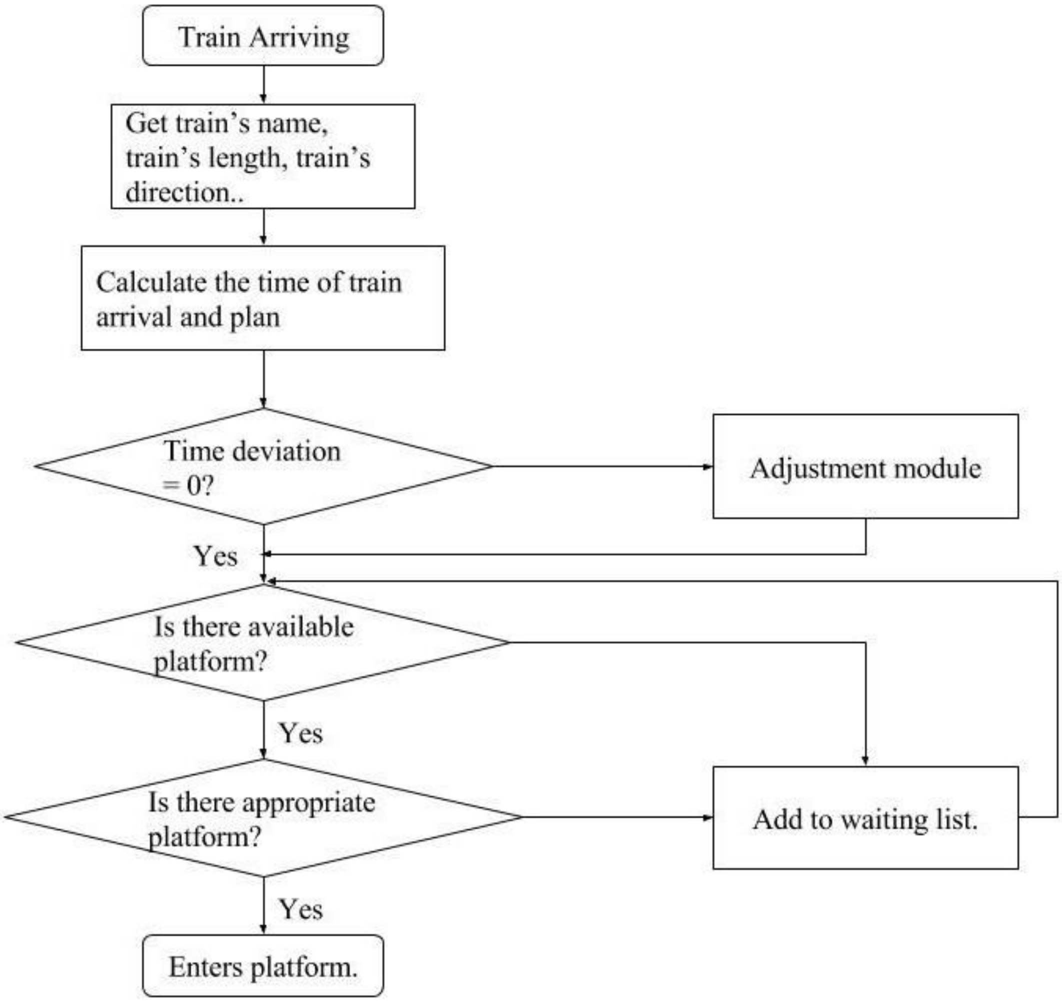

Figure 4.2 Arrival related process flow

When the train arrives, the condition of train and platform changed, touching off the check of each of the train's situations. Knowing the original arrival time and the actual arrival time, the system can get the running state by calculating, to determine whether it deviates from planned operation. Once the train is judged to be out of normal operation, it will automatically adjust.

4.5.2 The train waiting processing flow

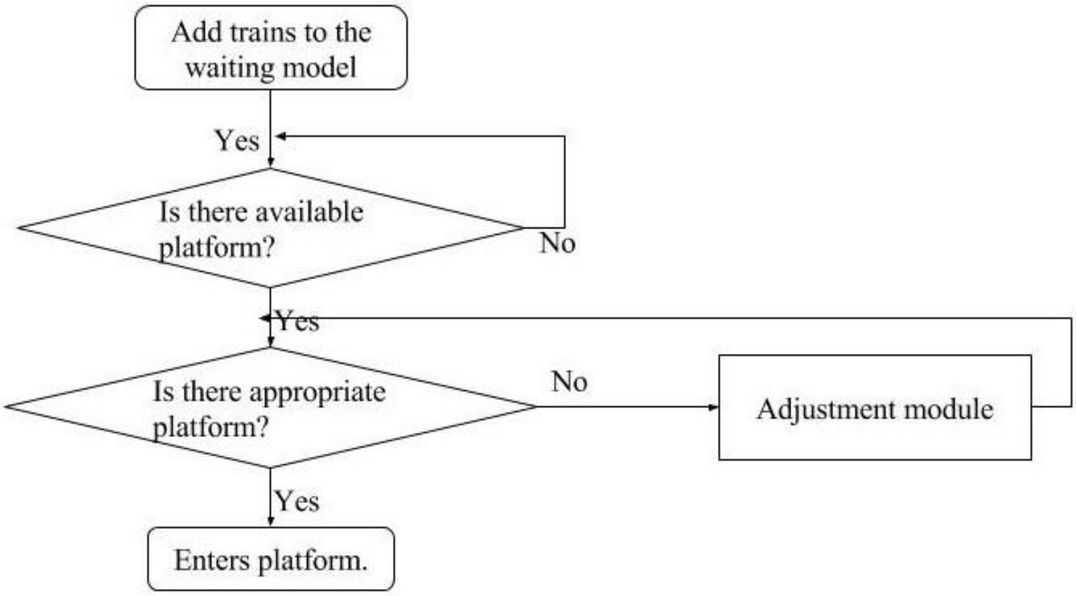

Figure 4.3 The train waiting process flow

The program has a waitTrainList, which store the waiting train's information. After observation of empty platforms/appropriate platforms, this system let the waiting trains entering first.

4.5.3 The train automatically adjustment related processing flow

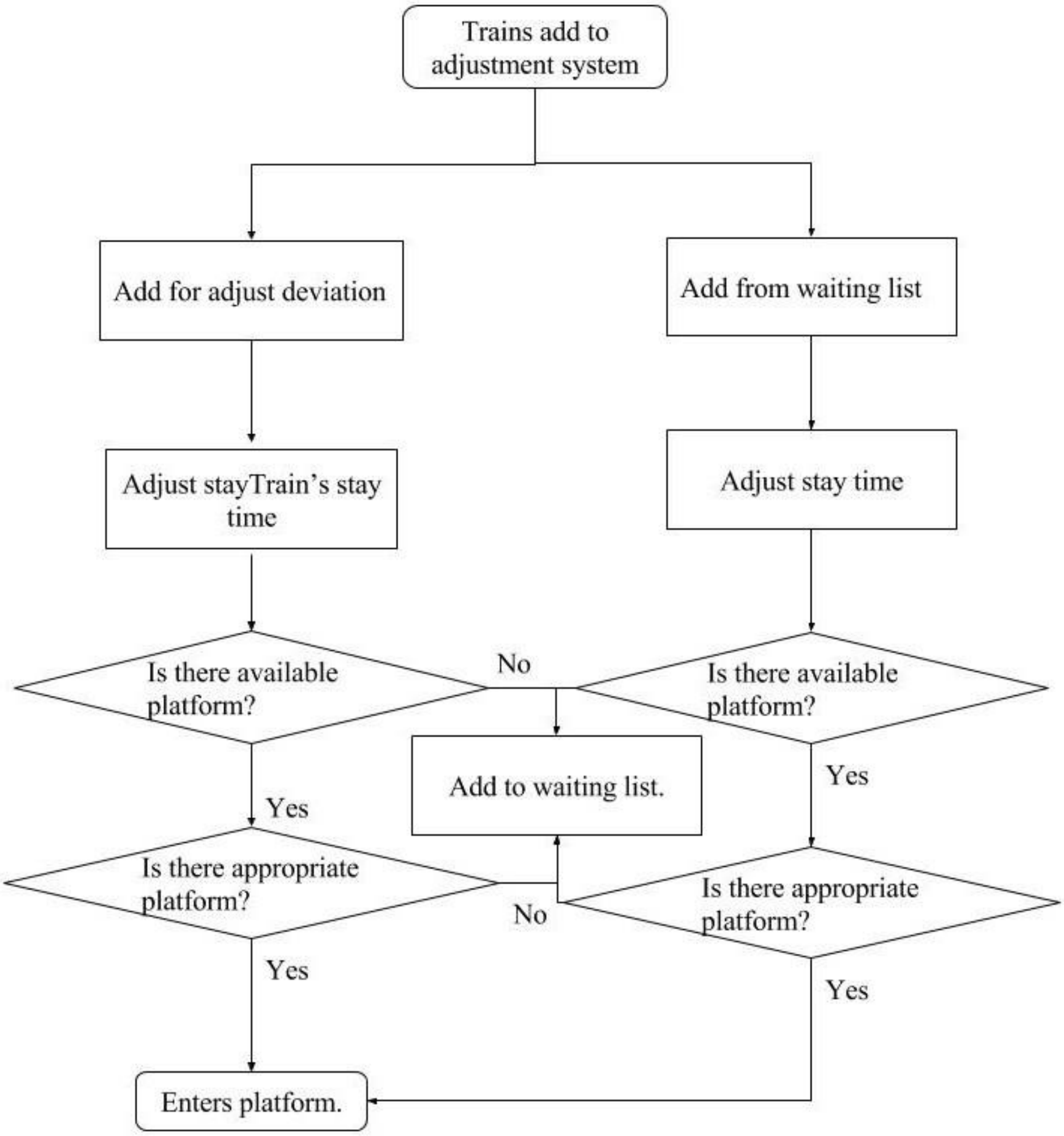

Figure 4.4 Atomatically adjustment related processing flow

According to 4.5.1, the automatically adjustment, not only depends on the real-time schedule, but also the maximum and minimum stop time range.

4.5.4 The train skips a stop (bypass) related processing flow

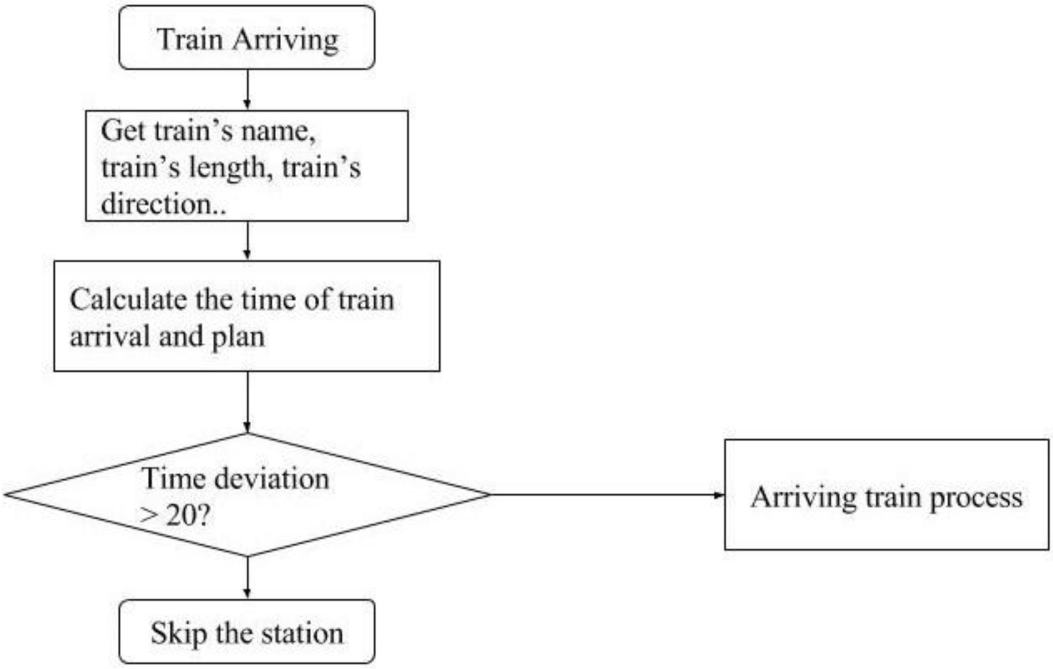

Figure 4.5 The train skip the station related process flow

When the train select to skip a stop, this train should not be the last train. At the same time, in routine operation, the skip a stop order for the same type of train will not be issued to two adjacent two trains at the same time.

Chapter 5: Coding and testing

In this chapter, the report explains the coding design and how the testing part works. The 5.1 will show how to write this program, and the structures of this code. Section 5.2 introduced the meaning of the testing part.

5.1 Program design

Figure 5.1 represent the process flow of the whole Expert System. The program could separate into four parts. Trains, Platfroms are two basic elements of this system, the expert system and calculation system offered methods to support the system. Create elements in its structure and add them into the schedule, using methods to produce situations and then solve them, finally output the result.

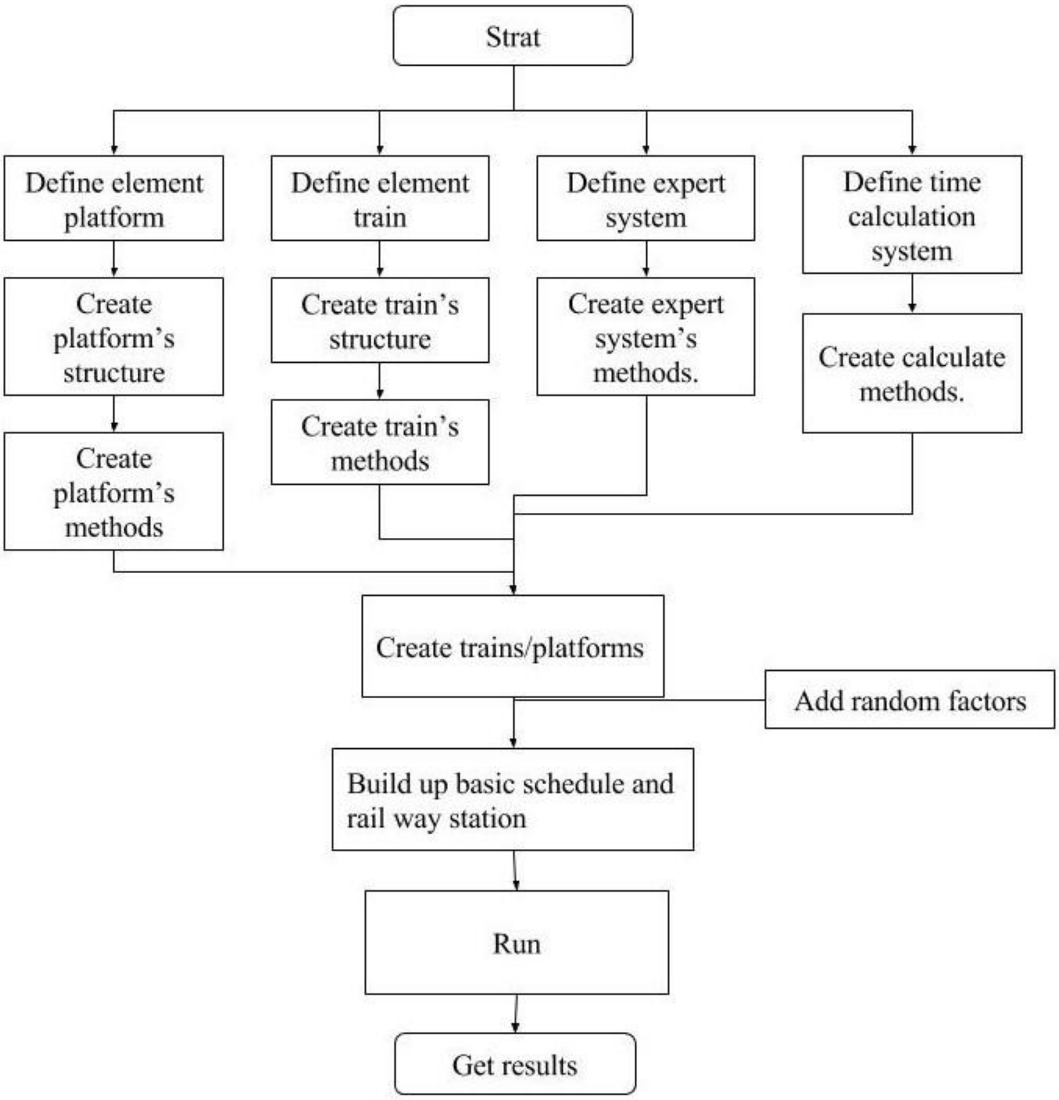

Figure 5.1 The Expert System coding process flow

5.2 Program methods

5.2.1 Class Trains

Create a train's structure which has 10 attributes (trainName, trainLength, trainFrequency, trainArivTime, trainStayTime, trainArivDirec, trainDeparDirec, trainType, trainStatus and trainOcupPlat) at beginning, and rests are get() methods and alter methods.

5.2.2 Class Platforms

Platform's properties are platNumber, platLength, platRelsTime, platDirec, platStatus. And get methods, change methods are same as trains.

5.2.3 Class TheExpertSystem

In class TheExpertSystem, there are all reasoning methods, as a inference engine. Methods trainDeparture, trainWaitTreat, trainArrivl are the basic approachess to cover all the situations which may happens during the operation.

5.2.4 Class TimeMethods

All calculating (time) methods are in this class.

5.2.5 Class RailwayStation

This class is the where the main method is, after create trains, platforms and add them into trainList, platList, the preparation has been done. And there are is a clockTime in the model, it shows time when the system works.

Trains Attributes:
Train Name
Train Length: 0: short.1: long.
Train Frequency (minutes)
Train Arrival Time
Train Stay Time
Train Arrival Direction: 0: none.1: east.2: west.
Train Departure Direction: 0: none.1: east.2: west.
Train Type: short.long.major city.
Train Status: 0: None 1: The train already entered the station. 2: The train is waiting for entering the station. 3: The train is waiting for an empty/approprate platform; 4: The train going through the station. 5: The train is already leaving.

Platforms Attributes:
Platform Number

Platform Length: 0: short.1: long.

Platform Release Time

Platform Direction: 0: none.1: east.2: west.

Platform Status: 0: The platform is available.1: The platform has been occupied.2: The platform is closed.

5.3Testing

```
Time: 23:18
TP: 3; EP: 2; ST: 1; WT: 0; FV: 5/222.

The Longtrain(23:20) is arriving.
The Longtrain(23:20) enters the platform 3
The Longtrain(23:20) was 2 minutes earlier.
Due to the situation, the stay time of Longtrain(23:20) adjust to 12 minutes.

Time: 23:19
TP: 3; EP: 1; ST: 2; WT: 0; FV: 5/224.


Time: 23:20
TP: 3; EP: 1; ST: 2; WT: 0; FV: 5/224.

The MajorCityTrain(23:00)was departured from the platform 2
```

Figure 5.2 Output in console

Figure 5.2 is part of the program's output in the software console. There are some information shows directly like: clock time, station's status, happening events and adjustments.

The station's status is: Total platforms number, Empty platforms number, Stay trains number, Waiting trains number and the Fitness value. And the FV means: Actual deviation minutes that events caused/ Total deviation minutes.

Chapter 6: Results and discussion

In this section, the report will collect results and analysis these outputs. Because this system runs randomly every time, so run several times will have a better performing.

6.1 Result analysis

.

```
Time: 04:00
TP: 3; EP: 3; ST: 0; WT: 0; FV: 0/0.

The MajorCityTrain(04:00) is arriving.
The MajorCityTrain(04:00) enters the platform 2
The Longtrain(04:00) is arriving.
The Longtrain(04:00) enters the platform 3
The ShortTrain(04:00) is arriving.
The ShortTrain(04:00) enters the platform 1
```

Figure 6.1Train arriving and entering

Figure 6.1 shows the normal operations that when train arrived and the station has appropriate platforms, and then train enters. And we can observe that the station's status has been changed at 04:01 (Empty plats number: 3-0, Stay trains number: 0-3)

.

```
Time: 04:01
TP: 3; EP: 0; ST: 3; WT: 0; FV: 0/0.
```

Figure 6.2 Station's status

```
Time: 04:10
TP: 3; EP: 0; ST: 3; WT: 0; FV: 0/0.

The Longtrain(04:00)was departured from the platform 3
The ShortTrain(04:00)was departured from the platform 1

Time: 04:11
TP: 3; EP: 2; ST: 1; WT: 0; FV: 0/0.
```

Figure 6.3 Train departure

As figure 6.3 shows, when the clock time equals arrival time adds stay time, the train will departure. And station's condition will change.

```
The ShortTrain(04:30) is arriving.
The ShortTrain(04:30) enters the platform 1
The ShortTrain(04:30)is late for 2 minutes.
Due to the situation, the stay time of ShortTrain(04:30) adjust to 8 minutes.
```

Figure 6.4 Train stay time adjustment

When the train arrived later than its plan said, the train transport system will adjust this train's stay time. Because it's late, so the stay time will be reduce to let the train's departure time more similar as the time on the schedule.

```
Time: 04:39
TP: 3; EP: 2; ST: 1; WT: 0; FV: 0/2.

The Longtrain(04:40) is arriving.
The Longtrain(04:40) enters the platform 2
The Longtrain(04:40) was 1 minutes earlier.
Due to the situation, the stay time of Longtrain(04:40) adjust to 11 minutes.
```

Figure 6.5 Train stay time adjustment

Refers to the figure 6.4, when the train arrived earlier than the plan, the stay time will extended.

```
Time: 07:07
TP: 3; EP: 2; ST: 1; WT: 0; FV: 0/23.

The ShortTrain(07:00) is arriving.
The ShortTrain(07:00) enters the platform 1
The ShortTrain(07:00)is late for 7 minutes.
Due to the situation, the stay time of ShortTrain(07:00) adjust to 5 minutes.

Time: 07:08
TP: 3; EP: 1; ST: 2; WT: 0; FV: 0/30.
```

Figure 6.6 Train stay time adjustment 2

The figure 6.6 shows another situation of train stay time adjustment, while the stay time going to reduce to under 5 minutes, system let stay time equals to 5. Because this system do not let train's stay time under limitation, that if it is a short or long train, the limitation is 5, if it is a major city train, the limitation will be 10 minutes.

```
Time: 04:05
TP: 2; EP: 0; ST: 2; WT: 1; FV: 0/0.

Due to the situation (a train already waits for 5 mins or more),

Time: 04:06
TP: 2; EP: 0; ST: 2; WT: 1; FV: 0/0.


the stay tiime of MajorCityTrain(04:00) adjust to reduce 5 minutes, now it is 15 minutes.
```

Figure 6.7 Train stay time adjustment

As the figure 6.7 shows that when a train stays in waiting list 5 minutes or more than five minutes, the system will reduce the stay time of trains which in the stay train list. This adjustment makes this system more reasonable.

```
Time: 04:15
TP: 2; EP: 1; ST: 1; WT: 1; FV: 0/0.

The MajorCityTrain(04:00)was departured from the platform 2
The Longtrain(04:00) enters the platform 2
```

Figure 6.8 Train stay time adjustment result

And in figure 6.8, after adjustment, the major city train departure after staying 15minutes (20-5), and the long train immediately entering the platform 2.

Besides the situation solution (adjustments), there are is a more intuitional result, the fitness value.

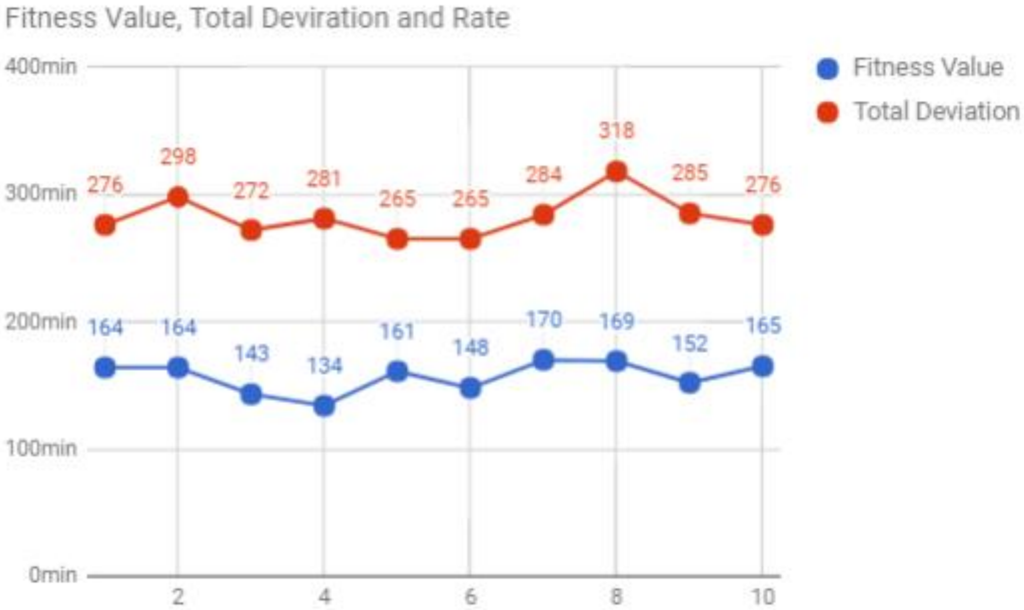

Figure 6.9 Line charts 1-1

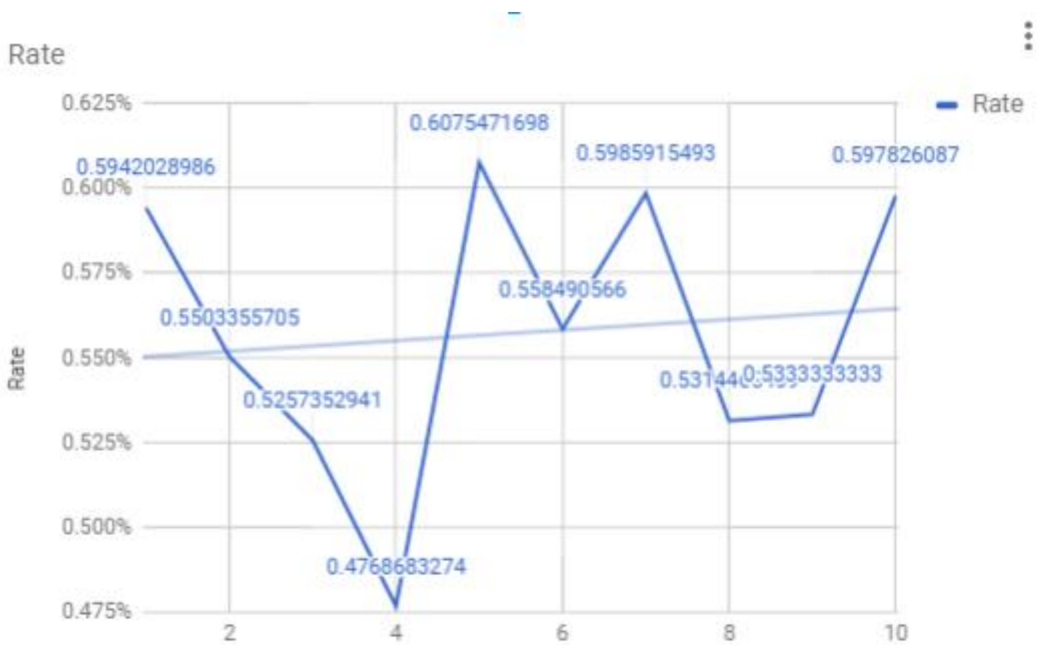

Figure 6.10 Line charts 1-2

Figure 6.9 and 6.10 shows that when there are 2 plats and same directions, 91 trains' performance in this expert system. Due to there are only two platforms, and too many situations, the rate of reducing deviation time is around 45%.

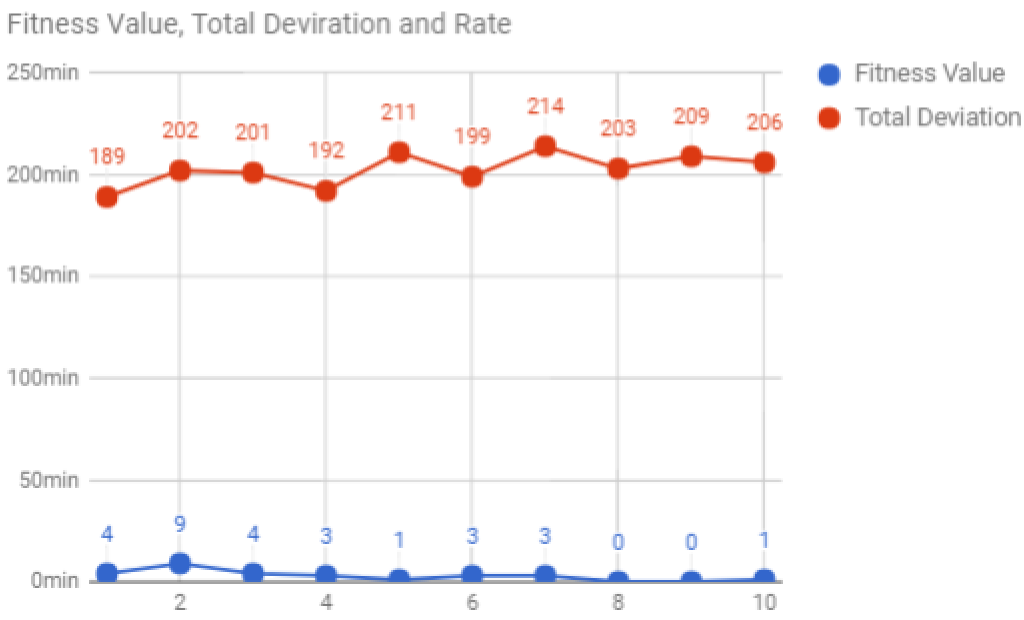

Figure 6.11 Line charts 2-1

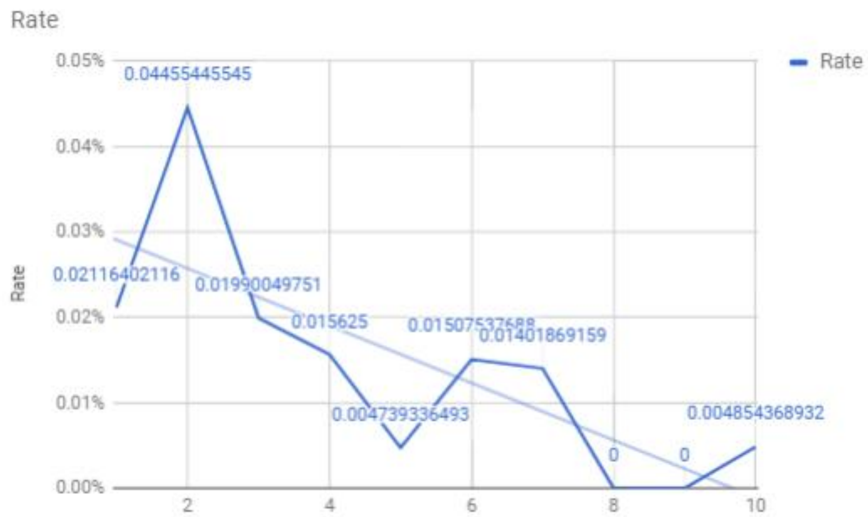

Figure 6.12 Line charts 2-2

Unlike Figure 6.9, 6.10, figure 6.11 and 6.12 shows this system performs well when there are 3 platforms even different directions. The total number of trains is 93, same as chart 1.

6.2 Goals achieved

In conclusion, all these results can prove that the Expert System is a reasonable method to find optimal scheduling of trains at a station, but when faced difficult situations, the performance of the expert system is not satisfactory.

Figures 6.1-6.8 shows, all these situation can be discovered and can be solved on time. Figures 6.9-6.12 shows the efficient of the Expert system.All these shows that this Expert System meet the requirements of this project, that it can deal with situations and can reduce time loss during the operations, and it does make sense.

For the program, it achieved the most requirements and aims in chapter 3. In the console, user can observe all the events and it is easy to know how does the system works through the station's status.

In the aspect of results, all the data in this Expert System are observed and operable. It is very convenient that all the results show in the console.

6.3 Further work

While the aims and objectives gave been achieved, there are still some aspects or points haven't been concerned:

1. Do research on the project using other methods, like genetic algorithm..
2. Even for the Expert System, there are several kinds of expert system, maybe other model will performance better.
3. This Expert System can be more flexible, because there are still have some hard code.

Chapter 7 Conclusions

In this report, using Java programming language to write and implement the rule-based Expert System to find optimal scheduling of trains at a station, by setting rules, defining constraints, and formulating adjustments. It is a huge challenge due to lack of knowledge in this field and unfamiliarity with the approaches. This project researched on the Expert System and the train transport system; finally getting the result that it is reasonable to find the appropriate optimal scheduling of trains at a station.

As for the project, there are still many shortcomings to be improved, that should avoid the weaknesses of various Expert Systems, make the entire system more complete and reasonable, and at the same time, there is still a lack of heuristic use.

This report began with an introduction, and then describes backgrounds and aims, objectives of this project. In Chapter 2, it focuses on the history of "Optimal Scheduling of Trains" and the methods people have used to solve this problem. Finally, this report explained the Expert System and the Java language to lay a good foundation for the later chapters.

The following section presented the detailed requirements and analysed the whole Expert System of this project. Next, a brief introduction of the testing plan was pointed out.

Chapter 4 shows how to create a basic schedule timetable of all the trains and the reasons for choosing the Expert System and Java. Besides, a rule-based Expert System was built up by design for every part of the system.

Chapter 5 explained how to write the Java program and formulate the testing part which includes the testing standard and the output of this program.

The next section showed the results obtained from the program and then expanded the discussion about these results.

In conclusion, this project used the rule-based Expert System written in Java to find the optimal scheduling of trains at a station.

References

[1] Van Dyke, C. and Meketon, M. (2017). Train Scheduling.

[2] Szpigel B．，Optimal train scheduling On single track railway[J]. Operation Research，i972， (20)：343—351．

[3] Jovanovic D．，et a1．Tactical Scheduling of Railway Operations：the Scan 1 Systems[J].   Transportation Science，1991。25(1)：46-64．

[4] Jovanovic…D et a1．Decision Support System for Train Dispatching：An Optimization--Based Methodology[J]．Transportation Research，1990．131(4)：3 1-40．

[5] Cao, Jiaming. Optimization model and algorithm for train operation adjustment of single track railway[J]. Railway Transaction, 1994, 16(3): 72-79

[6] Xu, Xiaoming & Li, Ke-Ping & Yang, Lixing. (2015). Rescheduling subway trains by a discrete event model considering.

[7] Cai, Zixing, Durkin J, Gong Tao. Advanced expert systems: principles, design and applications, [M]. Beijing: Science Press, 2006.

[8] Liao S H.Expert system methodologies and applications - A decade review from 1995 to 2004[J]. Expert Systems with Applications. 2005.28(1):93-103

[9] ShiueW, LiST, ChenKJ.A frame knowledge system for managing financial decision knowledge[J]. Expert Systems with Appllications, 2008, 35(3): 1068-1079.

[10] Wu, Mingqiang. Shi, hui. Zhu, Xiaohua. Et al. Current situation and Prospect of fault diagnosis expert system [J]. Computer measurement and control, 2005, 13 (12): 1301-1304

[11] Zhang, Daisheng. Wang, Rui. Chen, Chaoyang. Vehicle fault diagnosis expert system based on case-based reasoning and rule-based reasoning [J]. Journal of mechanical engineering, 2002, 38 (7): 91-95

[12] ChouJS.Generalizedli near model=-based experts system for estimating the cost of transportation projects[J]. Expert System Application, 2009, 36(3): 4253-4267.

[12]ChouJS.Generalizedlinearmodel-basedexpertsystemfores-timatingthecostoftransportationprojects[J].ExpertSystemswithApplications，2009，36（3）：4253-4267.

[13] Liao, SH. Chen, JL. Hsu, SH. Ontology-based data mining approach implemented for sport marketing[J]. Expert Systems with Applications, 2009, 36(8): 11045-11056.

[14] Zhang, Yudong. Wu, Lenan. Wei, Geng. Cell image segmentation method based on particle swarm neural networks [J]. Journal of electronic measurement and instrument, 2009, 23 (7): 56-62.

[15] Zhang, Yudong. Wu, Lenan. Wei, Geng. Study of neural network generalization and enhancement technology [J]. science and engineering, 2009, 9 (17): 4997-5002.

[16] Zhang, Yudong. Wu, Lenan. Wu, Gang. Comparison of neural networks and evolutionary algorithms in engineering optimization [J]. computer engineering and applications, 2009, 45 (3): 1-6.

[17] Zhang, YD. Wu, LN. Wei, G. A new classifier for Polari metric SAR images [J]. Progressing Electromagnetic Research, 2009, 94: 83-104.

[18] Amodio, P. Pellegrini, A. Ubiali, E. et al. The EEG assessment of low –grade hepatices encephalopathy: Comparison of an arificial neural network expert system (ANNES) based evaluation with visual EEG readings and EEG spectral analysis[J]. Clinical Neuro physiology, 2006, 117(10): 2243-2251.

[19] Cai, Zixing. Intelligent control [ll]. Beijing: Electronic Industry Press, 2004 edition, second.

[20] Zhang, Huaguang. Meng, Xiangping. A basic theory and application of intelligent control [M]. Beijing: China Machine Press, 2005