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An Intelligent Tutoring System for Teaching the Stroke Orders of Chinese Characters on the Internet

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Abstract

This paper presents an Intelligent Tutoring System (ITS) for teaching the stroke orders of Chinese characters through the Internet. Since each Chinese character is like a picture, the correct stroke orders can get a more easily and comfortably writing behavior. So, it is important to learn the correct stroke orders for writing the Chinese characters. Based on these reasons, the correct stroke orders of Chinese characters are taught in primary schools at Taiwan. In the proposed system, students can use the mouse to write (i.e., drag the mouse) a Chinese character on the browser (e.g., Microsoft Internet Explore). The writing behavior of each student will be learned by the neuron-based student model. When a wrong stroke order is written, a short animated cartoon movie will be shown to warn the student, and the reason of errors will be explained. An intelligent tutoring module in this system will select a Chinese character, which is similar to the wrong stroke order's character, to teach the student again. Many databases and rule-bases are used to store the important information, such as the correct stroke orders and the structure of each Chinese character, the writing behavior of each student, the inference rules for selecting the training character, and the error codes (types), etc. Students can enjoy in this ITS to learn the correct stroke orders of Chinese characters on the Internet. This system had been developed since 1996, and been operated by more than one thousand people. Experimental results show that there are more than 82% primary students who can't write the correct stroke orders of Chinese characters. The proposed system is verified that has a high value to teach students on learning the correct stroke orders of Chinese characters. In addition the neuron-based student model and the intelligent tutoring model successfully extend the applications of artificial intelligence (AI).

Keywords: Intelligent tutoring system (ITS), Internet, Stroke orders of Chinese characters, Artificial intelligence (AI).

1. Introduction

There are more than four thousands Chinese characters that often be written, and they have wide varieties of shapes and the stroke orders. Before writing the Chinese characters, it is required to learn the correct stroke orders of the characters. Because each Chinese character is like a picture that each stroke has a special shape and direction, and is located at a specified position in the character. Then, the correct stroke orders (defined by the Ministry of Education, Taiwan, 1996) of a character can be written more easily and comfortably, in addition the written characters would be more understandable and beautiful. Based on these reasons, the correct stroke orders of each Chinese character are taught in primary schools at Taiwan. However, it is impossible for a teacher to verify the correctness of stroke orders of characters written by each student in a 30-students classroom. Then, an Intelligent Tutoring System (ITS) [1] is required to help students on learning the correct stroke orders of Chinese characters.

The researches of CAI (Computer-Assisted Instruction) have been developed for the past two decades. Many quite well systems such as the declarative model's SCHOLAR [2, 3], the black box model's SOPHIE-I [4], the qualitative model's SOPHIE-III [5], the glass box expert model's

GUIDON [6], the procedural knowledge model's BUGGY [7], and the neuron-based ITS [8], etc. had been designed. But most of the CAI systems are operated in personal computer only. It can't let users operate through the Internet, and the researchers can't gather a great of data on time during operating on the CAI system. Therefore, "how to design a CAI system on the Internet" becomes a great and extreme important work for achieving the remote learning. In addition, "how to apply the artificial intelligent techniques to the CAI systems" is also a critical issue for designing an effect learning system. The proposed ITS considers these two issues, and is designed by combining the new developed AI technique "neural network" [9, 10, 11] and the WWW programming technique "Active X control" and "ODBC" [12, 13]. Such that the proposed ITS can provide an effect environment for learning the stroke orders of Chinese characters on the Internet.

In the section 2, we will introduce the system architecture of the proposed ITS. In the section 3, the applied artificial intelligent techniques will be explained. Section 4 shows the experimental results and the conclusions are discussed in the section 5.

2. System architecture

In the proposed ITS, there are seven major parts: the user interface, the student model, the intelligent tutoring module, the instruction/test module, the explanatory module, the data- and rule-base module, and the multimedia animated cartoon engine (as shown in figure 1), etc. Figure 2 shows the architecture of the proposed ITS on the Internet.

Each displayed Chinese character on the user interface is specified by the pixel-location of the screen (i.e., denoted by the positions of X- and Y-coordinate). Each stroke is recorded by two (X,Y) positions. The first position is the initial part of the stroke, and the last position is the final part of the stroke (as shown in figure 3). For example, the stroke "ノ" in the upper-left part of the Chinese character "伶" (shown in figure 3) is recorded by (93,46) and (22,151).

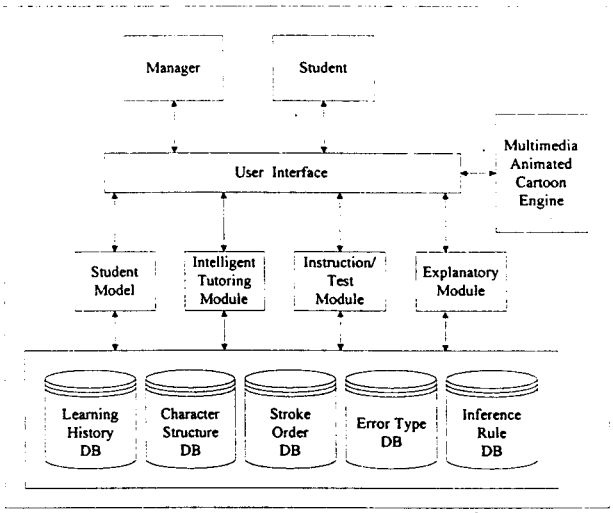


Figure 1. The structure of the proposed ITS for teaching the stroke orders of Chinese characters.

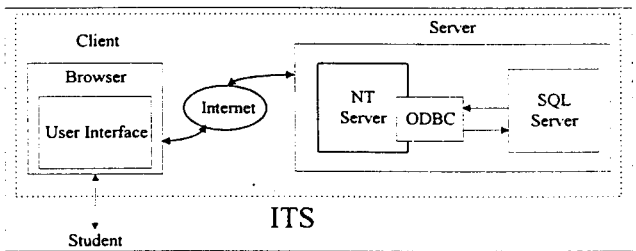


Figure 2. The architecture of the proposed ITS on the Internet.

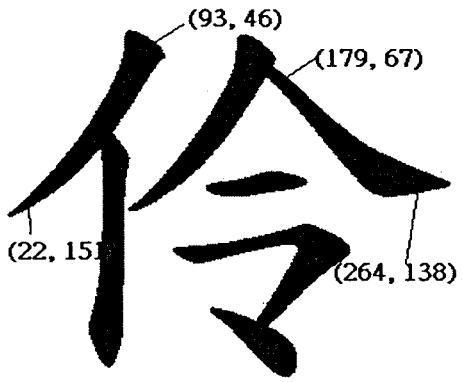


Figure 3. The position encoding method for showing Chineses characters on the screen.

Therefore, the stroke orders of a Chinese character can be recorded by a sequence of (X, Y)-positions. In addition each stroke must also consider the "direction". We define eight different directions for representing the stroke of Chinese characters (as shown in figure 4).

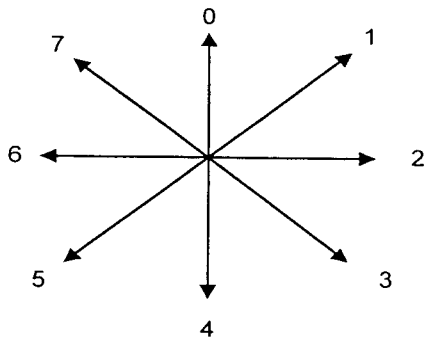


Figure 4. The direction encoding method for representing the stroke of Chinese characters.

Such as a stroke is written from the upper-right to the lower-left, the direction is "↙" and will be coded as "5". For example, the Chinese character "天" is written by the following direction sequence "→, →, ↙, ↘" , and the direction codes will be "2, 2, 5, 3". For ease of operation, the interface of the system is designed to operate by using the mouse or touch panel monitor that supports a user-friendly environment. When a student writes (i.e., drags the mouse) a Chinese character on the browser, the dragged part will display a different color (as shown in figure 5) which likes to write a character on the paper by the pen. The stroke orders of written characters would be recorded in the history database and learned by the student model.

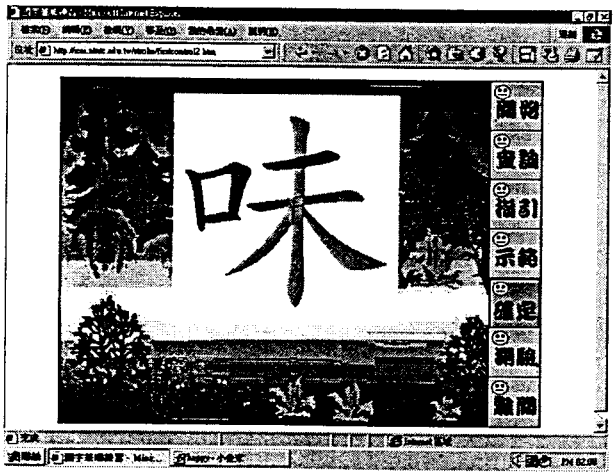


Figure 5. The user interface of the proposed ITS for writing Chinese characters on the Internet.

If the written stroke orders are correct, then a joyous cartoon movie, produced by the multimedia animated cartoon engine, is shown as a reward (as shown in figure 6).

Figure 6. A joyous cartoon movie is shown as a reward to the student.

And then another Chinese character, with different stroke orders, will be generated for instruction. However, an incorrect written stroke order will incur an warning cartoon movie to display (as shown in figure 7), and the explanatory module automatically responses an error message (i.e., explain the error reason) to help the student to realize his (or her) actually misconception (as shown in figure 8).

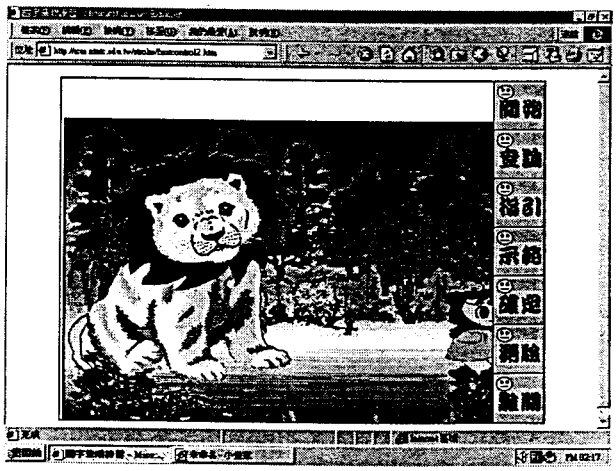


Figure 7. A warning cartoon movie is shown as a punishment to the student.

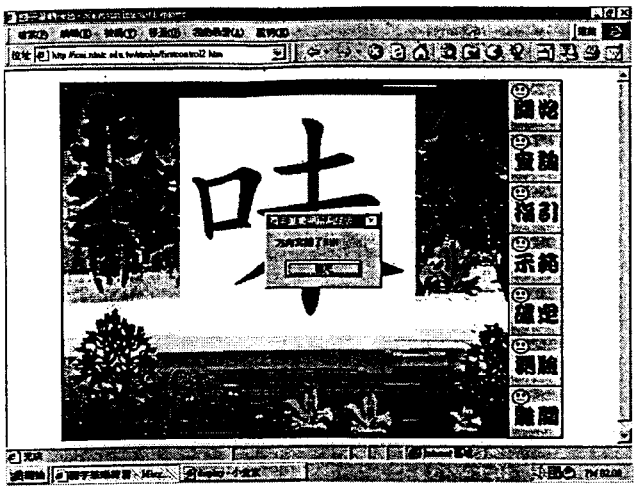


Figure 8. An error message "an error direction of the written stroke" is shown to note the user.

After that the intelligent tutoring module will response a Chinese character which is similar to the wrong stroke order's character, to the student for rewriting and relearning this stroke. On the user interface, there are seven functions are applied (as shown at the right part of figure 5). The basic operations of each function are discussed as follows:

Function (1) "開始" initiates the instruction/test module and produce a learning environment.

Function (2) "查詢" retrieves the records from the history database, and shows the results of ten most recently written Chinese characters (as shown in figure 9).

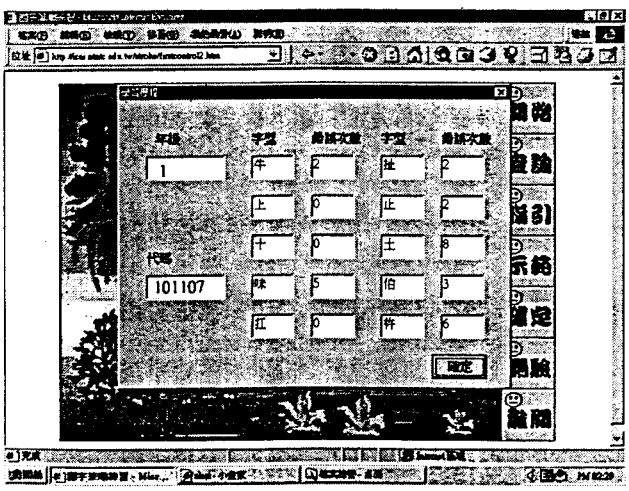


Figure 9. The pumped window shows the written Chinese characters and the number of errors.

The returned information contains ten written Chinese characters and the digit, following each character, represents the number of errors during writing this character. The reasons of errors are also recorded in the learning history database, and are used by the explanatory module.

Function (3) "指引" directs the next stroke during writing a Chinese character, when the student doesn't know how to write the next stroke of this Chinese character. The next stroke will be written and shown by the system and disappears after 3 seconds. Then, the student can write and learn the correct stroke orders by following this direction.

Function (4) "示範" demonstrates how to write the stroke orders of the displayed Chinese character. After 3 seconds, the written strokes will disappear and then the student can write the correct stroke orders of this Chinese character by following the demonstration.

Function (5) "確定" is used to note the system that the displayed Chinese character has been written completely and is ready to write/learn the next Chinese character.

Function (6) "測驗" is a test mode which is similar to function (1). But there is no any error message to return during writing the Chinese characters. However, when a test is finished, a score will be shown to the student and the writing behavior of these characters becomes the training patterns of the neural network in the student model (the detail will be discussed in section 3).

Function (7) "離開" is used to exit the ITS, and if the student wants to practice/learn again, then he (or she) must be re-log in by keying the user ID and the password.

Above seven functions are implemented by the instruction/test module, and the errors are handled by the explanatory module.

Two parts in the system are developed by the artificial intelligent techniques. The first one is the student model [14] that is designed and developed by the Neural Network (NN). Such that the writing behavior of the student can be learned by the student model. And then the system can simulate

internally and predicts the stroke orders of unlearned characters. If the student's written-stroke of a character is incorrect, then the student has a high possibility to write the wrong stroke orders for some unlearned characters that are similar to this character. Thus, the predicted characters by the NN will be used to test and teach the student for correcting the wrong writing behavior. The student only requires to practice by a small subset of Chinese characters but writing more than thousands of Chinese characters.

The second one is the intelligent tutoring module that is implemented by the rule-based system [15]. A wrong stroke order may involve many factors (e.g., the wrong direction or the wrong sequence). The intelligent tutoring module will select a character, which contains the same properties as the wrong stroke orders, to teach the student. The selected character contains the most information about the wrong stroke orders written by the student. Such that the student doesn't require to writing many Chinese characters, which are unrelated with the wrong stroke orders. And then students can learn more efficiently during operating on this system.

3. Applied artificial intelligence techniques

In the proposed ITS, two artificial techniques, the neural network and the inference engine (rule-based system), are used to develop the student model and the intelligent tutoring module.

3.1 The student model

Figure 10 shows the architecture of NN for learning the writing behavior of a student. The proposed NN is a multi-layers perceptron (MLP) structure, and the states of input neurons are the correct stroke orders of a Chinese character, which shift left at every time period. The neuron at the "target" position will be learned by the output neurons. Then, the initial stroke starts from this position, and the inputs are shifted left at the next time period for learning the next stroke of the character, and so on. The learning and shifting processes will continue until all strokes are trained

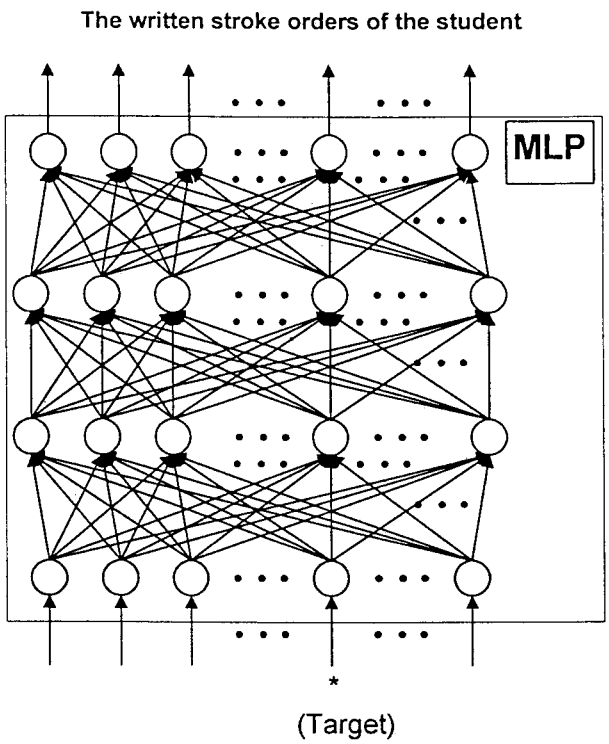
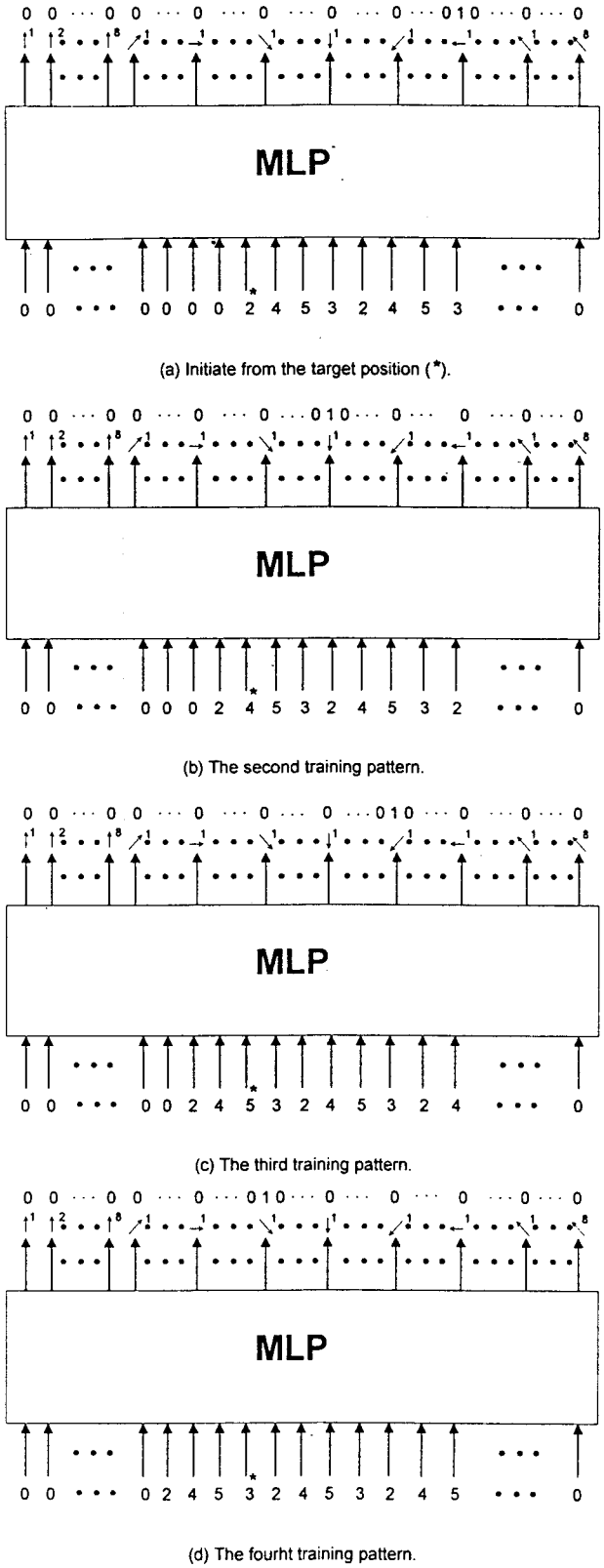


Figure 10. The architecture of NN for learning the writing behavior of a student.

and learned. The output neurons contain all stroke orders in Chinese characters. So, each stroke direction must be considered in the output and there may be many strokes with the same direction in a Chinese character. For example, the Chinese character "森" has three strokes with the same direction "→", which will correspond to the output neurons: $\rightarrow^1$, $\rightarrow^2$, and $\rightarrow^3$. For each output neuron D^j, the upper index j represents the order of the stroke on the direction D. Based on the above example, the upper "木" in the Chinese character "森" is written first, and followed by the lower-left "木", and then the lower-right "木" is written. The stroke orders of "森" are "→, ↓, ↙, ↘, →, ↓, ↙, ↘, →, ↓, ↙, ↘" and the direction codes are "2, 4, 5, 3, 2, 4, 5, 3, 2, 4, 5, 3." Suppose the direction of stroke "—" written by a student is incorrect, whose written direction is "←" instead of "→." Then the direction codes of "森" written by this student are "6, 4, 5, 3, 6, 4, 5, 3, 6, 4, 5, 3." Figure 11(a) ~ (d) show the first four training patterns of the NN for learning the first

four strokes of written Chinese character "森".



(a) Initiate from the target position (*).

(b) The second training pattern.

(c) The third training pattern.

(d) The fourht training pattern.

Figure 11. (a) ~(d) show the first four training patterns (stroke orders) of the NN.

There are twelve strokes (training patterns) of "森" to be learned by the NN. After applying the learning technique (delta learning rule) [16], the student's writing behavior can be learned. Then, another similar input pattern will generate the same output. For example, if a similar Chinese character "林" is written by this student, then the written direction codes would be "6, 4, 5, 3, 6, 4, 5, 3" (an error direction for the stroke "—") but "2, 4, 5, 3, 2, 4, 5, 3." The experimental research had verified that the neuron-based student model can successfully learn the writing behavior of a student. Such that each student writes a sequence of stroke orders (we don't care the stroke orders are correct or not) will be learned by a NN in the student model. Then the NN will generate the same output (i.e., produce the same writing behavior of the student) for an unwritten Chinese character, which has the similar stroke orders as the previously learned character. Experimental results show that the neural network technique can successfully predict a student's unlearned characters, which will induce the wrong stroke orders. The neural network technique is more powerful than the rule-based system for its robustness and flexibility. The neuron-based student model is very suitable in the proposed ITS.

3.2 The intelligent tutoring module

There are seventeen major rules, defined by the Ministry of Education, for writing the Chinese characters. Based on these rules, a rule-base is constructed by combining these rules and the directions of strokes. Errors are analyzed and divided into three different types.

The first type of error is called by the *structure error*. Since each Chinese character often contains two or more "sub-character" which is also a Chinese character. For example, the Chinese character "味" contains two sub-characters "□" and "未." The correct stroke orders are to write the sub-charter "□" first and then to write the sub-character "未." If a student wrote the sub-character "未" first and then wrote the sub-character "□", then a *structure error* occurred.

The second type of error is defined as *sequence error*. For the Chinese character "未",

the correct stroke orders are the sequence "一, 一, 丨, ノ, 丶." If a student wrote the strokes with the sequence "丨, 一, 一, ノ, 丶", then a *sequence error* occurred.

The third type of error is called by the *direction error*. For the Chinese character "未", the correct direction of stroke "一" is "→". If a student wrote the stroke "一" by following the direction "←", then a *direction error* occurred.

These three types of errors are combined into an error code to represent the wrong writing behavior. Based on the error code, three databases are used to select the Chinese characters, which have the same properties within the error code. An inference engine is designed to analyze the selected Chinese characters by inference rules. After applying inference rules, a Chinese character with the most information about the error code is selected to retrain and correct the student's writing behavior. Figure 12 illustrates the operating flow of the inference engine for selecting a Chinese character "吐" with the maximum information of the error code (i.e., wrong writing behavior of the student). In this way, the student can learn the correct stroke orders of Chinese characters under an intelligent and efficient environment.

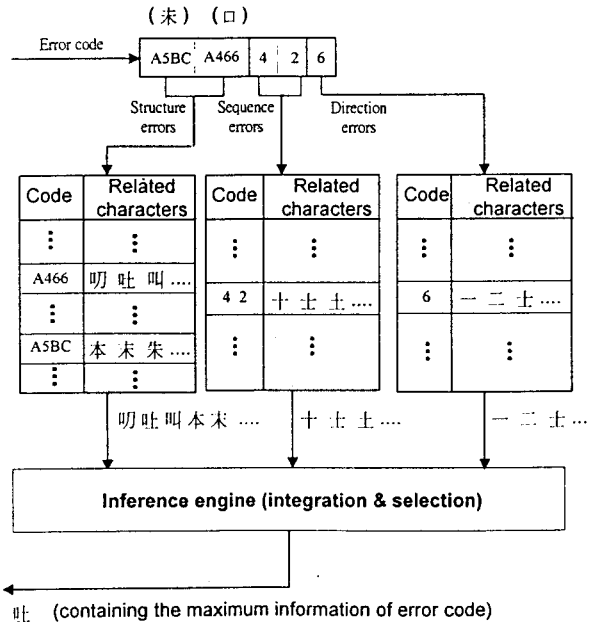


Figure 12. The operating flow of the inference engine in the proposed ITS.

4. Experiment results

The prototype of this ITS had been constructed and shown in the 1997 Children Information Show (sponsored by the National Science Committee, Taiwan) at Taipei and Kaohsiung. There are more than one thousand people to operate on the prototype system, and the collected data shows that the incorrect stroke orders of written characters are beyond 80% (see Table 1).

An experimental research is also designed and proceeded by randomly selecting 300 students from primary schools to use this system. The experimental results show that more than 82% of 300 students whose written stroke orders of tested Chinese characters are not completely correct. The major reason, we think, is that teachers can not realize students' stroke orders which are correct or not by checking the written characters on the paper. So, teachers can not instruct and correct the wrong behavior of students. An intelligent tutoring system becomes necessarily and importantly.

5. Conclusions

In this paper, we propose an ITS for assisting students to learn the correct stroke orders of Chinese characters. In the system, many new techniques are involved such as the neural network, the inference engine, the multimedia animated cartoon engine, the educational research, and the programming techniques on WWW, etc. It can instruct the student to learn the correct stroke orders of Chinese characters on the Internet. In addition two artificial intelligent techniques are designed to enhance the effect and power of this ITS. It helps students to learn the correct stroke orders of Chinese characters more intelligently and efficiently. The experimental research also shows that more than 82% primary students whose writing stroke orders are incorrect. This verifies that an ITS is required to assist students on learning and writing the stroke orders of Chinese characters. The proposed ITS will be a very useful tool, which will have a great contribution to the Chinese education. In addition the designed ITS also extends the applications of the artificial intelligence. The related researches can follow this

way to use the AI techniques to the computer-assisted instruction systems, and then the CAI systems become more efficiently and powerfully.

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Table 1. The statistics of the written Chinese characters (partial) in the 1997 Children Information Show.

	Written Chinese characters (partial)							
	件	什	任	上	扒	扣	味	未
Total written No.	1017	994	984	978	1024	1142	1106	1143
Incorrect written No.	289	231	788	148	256	273	237	195
Incorrect ratio (%)	28.4	23.2	80.1	15.1	25.0	23.9	21.4	17.1